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CONTENTS

This issue of Metallurgist contained a eulogistic article on V. I. Lenin. Since this article did not contain any information on the current state of Soviet research or techniques in metallurgy, it was not translated.

THERMAL OPERATION OF HOT-BLAST STOVES WITH VARYING DURATION OF THE CYCLE

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Heat-Engineering Laboratory of the Kursk Metallurgical Combine
Translated from Metallurg, No. 4, pp. 4-8, April, 1960

The hot-blast stoves of blast furnaces represent regenerative heat-exchangers, where the process of heat transfer from the heating medium to the heated medium is divided into two periods: gas and air. In the course of the first period, the heat of the products of combustion is transferred to the checkerwork* of the hot-blast stove, where it is accumulated; during the second period, the accumulated heat is given up to the cold air.

During the gas period, the checkerwork does not accumulate heat uniformly. At the commencement of heating, the temperature head, i.e., the mean temperature difference between the products of combustion and the checkerwork, has its maximum value and the cold checkerwork absorbs the heat intensively. In the course of time, the checkerwork heats up, the temperature head diminishes and the heat transfer deteriorates; the checkerwork participates in the heat exchange to an ever decreasing extent, due to which the exit temperature of the products of combustion increases. The waste gas leaving the checkerwork carries away uselessly a certain quantity of heat, which reduces the efficiency of the stove. The efficiency increases with decrease in the temperature of the products of combustion, and decreases with increase in that temperature. The duration of the gas and air periods must therefore be selected so that as little heat as possible will be lost with the escaping products of combustion, thereby increasing the efficiency of the plant.

The hot-blast stoves of the blast furnaces of the Kursk Metallurgical Combine were designed and constructed for heating 2400-2500 nm^3/min of blast to 500-600°C and were equipped with movable burners of "Freyn" type having a rated capacity of up to 24,000 m^3/hr.

Due to the increase in the capacity of the blast furnaces the change-over to high top pressures and the addition of steam to the blast, it has been found necessary to increase the quantity of the blast and to raise its temperature to 800-850°C. The thermal capacity of the hot-blast stoves, as determined by the heating area and the condition of the checkerwork, was inadequate for this purpose.

The hot-blast stoves were therefore reconstructed, their heating surface being increased (Table 1) by increasing the height of the checkerwork by 2.85 m and reducing the cross section of the checker openings from 65 × 65 mm to 60 x 60 mm. Altogether, the heating surface of the checkerwork was increased by 18% after reconstruction. The thermal operation of the stoves was also substantially changed.

The consumption of blast-furnace gas for a cycle of the previous duration was increased from 20,000 to 26,800 nm^3/hr. Complete combustion of the increased amount of gas was ensured by supplying compressed air, since the delivery of the burner fans was found to be inadequate. The temperature of the products of combustion leaving the checkerwork was increased from 190 to 255°C, which reduced the efficiency of the hot-blast stoves.

The thermal balance sheets before and after reconstruction show that the efficiency of the stoves dropped from 77.7% to 72.3%, although the blast characteristics and the duration of the cycle remained the same. The drop in efficiency was caused by the considerable amount of heat lost with the escaping products of combustion, due to the increase in temperature of the latter. The efficiency may be kept at the former level by shortening the period of the cycle, since the flue-gas temperature is then reduced; this was possible, however, only after the introduction of a complicated control system for the stoves.

In addition to determining the thermal characteristics of the reconstructed stoves, the vertical and horizontal distribution of the gas and air flow in the checkerwork was investigated. For this purpose, chromel-alumel thermocouples were placed in the checkerwork of one of the stoves for recording the brick temperature (Fig. 1). Two rows of thermocouples were arranged in the upper, more active-heat-exchange zone, and one row in the lower part of the checkerwork. Each row contained three separate thermocouples measuring the brick temperature near the combustion chamber, in the central part and in the peripheral part remote from the combustion chamber. The thermocouple readings were recorded by means of an electronic potentiometer. The thermocouples had compensating leads for reducing the error of measurement.

The measurements showed that the checkerwork temperature at the measuring points was different for the gas and air periods even for the same row of thermocouples (Table 2).

The table shows that the checkerwork temperature was a maximum on all three levels on the side away from the combustion chamber, and was a minimum near the combustion chamber.

* Checkerwork, i.e., checkered brickwork—Publisher

TABLE 1. Technical Characteristics of Old and Reconstructed Hot-Blast Stoves

Elements of the hot-blast stoves	Before reconstruction	After reconstruction
Over-all height, m	37.49	40.57
Diameter:		
Shell (nominal), m	7.8	7.8
Between lining (internal), m	6.7	6.7
Thickness, mm:		
Walls	460	460
External wall of combustion chamber	690	690
Partition wall	575	575
Dome	450	450
Cross section of combustion chamber, m^2	3.99	3.99
Height of checkerwork, m	30.00	32.85
Heating surface, m^2		
Checkerwork	13800	16880
Combustion chamber	253	276
Dome	67	67
Total heating surface, m^2	14120	17223
Checkerwork characteristics		
Size of checkerwork brick, mm	185×55×150	170×50×150
Size of checkerwork openings, mm	65×65	60×60
Number of openings enclosed on 4 sides by brick	–	2100
Hydraulic diameter, m	0.065	0.06
Total active cross section of checkerwork, m^2	7.47	7.70
Active cross section of checkerwork per m^2 of surface, m^2	0.294	0.298
Heating surface of checkerwork per m^3, m^2	18.1	19.8
Volume of checker brick per m^2 of heating surface, m^3	0.0392	0.0354
Volume of brick per m^3 of checkerwork, m^3	0.708	0.702
Total volume of checkerwork, m^3	762.4	852.5
Total volume of checker brick, m^3	539.8	598.4

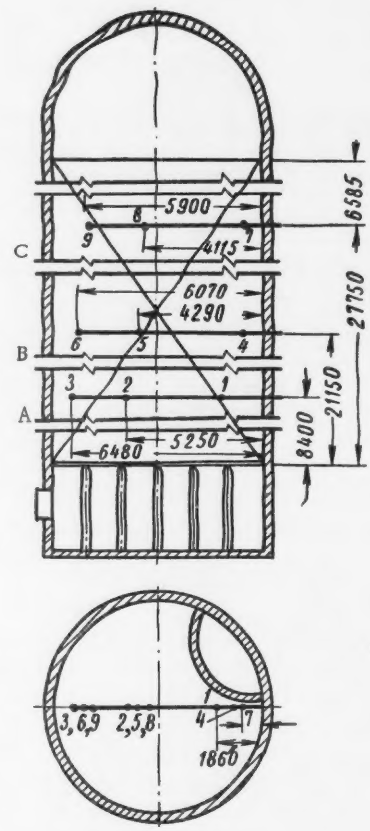

Fig. 1. Placing of thermocouple in hot-blast stove. A, B, C) Levels; 1,4,7) thermocouples for measuring the brick temperature near the combustion chamber; 2,5,8) thermocouples for the central part; 3,6,9) thermocouples for measuring the brick temperature in the peripheral part of the checkerwork away from the combustion chamber.

Such a temperature distribution points to irregularity in the flow of gas over the checkerwork cross section. The hot gases leaving the combustion chamber heat chiefly that part of the checkerwork which is away from the combustion chamber, while the part of the checkerwork near the combustion chamber is not heated so much. During the air period, the checkerwork is cooled just as irregularly. The main flow of air occurs in the region of the checkerwork near the combustion chamber. Such a distribution of the gas and air flow is undesirable from the point of view of the full utilization of the heat.

It is possible that the provisions of a diffusion grid on the partition wall of the combustion chamber would give a more even distribution of the products of combustion over the cross section of the checkerwork, but for this purpose, it would be necessary to try out such a grid on a model of a hot-blast stove.

Currently, the hot-blast stoves of the Kursk Metallurgical Combine are equipped with a complicated system for the automatic control of the blast characteristics, heating processes and reversing valves. Automatic maintenance of the predetermined temperature and humidity

of the blast ensures smooth operation of the blast furnaces. The system of automatic control of the heating process of the hot-blast stoves maintains the predetermined quantities of combustion gas and air, provides a check on the dome temperature and the combustion of the gas,and stops the burner fans at the proper time. The quantity of gas required for heating the stoves is regulated by butterfly valves mounted in front of each burner, and the quantity of air by the speed of the fans. The gas and air enter the burner in a definite ratio, since the angle of opening of the gas-regulating valve and the speed of the fan are strictly limited in the adjustment of the heating conditions as determined from a periodical analysis of the flue gas. Samples of flue gas taken from the space beneath the checkerwork are analyzed for CO_2 and O_2. The CO content and the excess air factor are determined from a specially constructed diagram. The following is an average analysis of the products of combustion: 24.4% CO_2; 2.4% O_2; 0.0% CO and α=1.35.

The dome temperature is regulated by a two-position regulator operating in conjunction with a chromel-alumel thermocouple type TX-VIII, mounted in the dome of the stove.

Formerly, the dome temperature was regulated by varying the excess air factor of the mixture. Now that the dome temperature is regulated by periodical reduction in the amount of gas, the burner capacity is utilized more fully, since there is no need to have a reserve of fan power for increasing the excess air factor. This reserve is advantageously utilized for burning the greater quantity of gas.

The moment of ignition of the gas, the combustion process and the disappearance of the flame are controlled by means of a photocell mounted on the burner towards the combustion chamber. On ignition of the gas, the photocell initiates a pulse for starting the fan motor; when the gas supply is cut off or the flame is extinguished, a pulse is released for stopping the fan and closing the gas cut-off valve, thus preventing the formation of an explosive mixture.

To increase the heating capacity of the hot-blast stoves, the old movable gas burners have been replaced by more powerful burners (Fig. 2) with a fan capacity of 40,000 m^3 of air per hour.

After the automatic control system had been fitted and the new burners provided, the thermal operation of the hot-blast stoves was also substantially modified. Originally, the blast was heated by four hot-blast stoves. The duration of the gas period was six hours and that of the air period two hours. It very soon became necessary, however, to abandon the eight-hour cycle since it was found to be uneconomical. The temperature of the products of combustion at the end of the gas period rose to 450°C, and the efficiency of the stove was low (72%). With the object of increasing the efficiency of the hot-blast stoves by reducing the amount of heat lost with the escaping products of combustion, the duration of the cycle was successively reduced to six, then to four and a half and then to three hours. Table 3 shows that the reduction in the duration of the cycle helps to reduce gas consumption and the temperature of the escaping products of combustion. The temperature of the products of combustion was reduced from 450°C for an eight-hour cycle to 270°C for a three-hour cycle. The efficiency increased correspondingly from 72.8 to 78.3%, i.e., by 5.5%. At the same time, the gas consumption fell by 5,000 m^3/hr. These results show the advantages of operating the hot-blast stoves on a shorter cycle. When the three-hour cycle was used, good results were obtained in regard to the further increase in blast temperature. Recently, the hot-blast temperature has been raised from 800°C to 900°C, and operation on blast with a temperature of 950°C is current-

TABLE 2. Temperature of Checkerwork During Operation of Hot-Blast Stoves

Measuring point	Temperature °C on		
	Lower level	Middle level	Upper level
At end of heating period			
Near combustion chamber	450	810	1100
In middle part of checkerwork	500	850	1140
In the peripheral part away from combustion chamber	520	880	1160
At the end of air period			
Near combustion chamber	260	530	810
In middle part of checkerwork	230	580	840
In part away from combustion chamber	280	630	880

TABLE 3. Calculation of Efficiency of Hot-Blast Stoves for Cycles for Different Durations

Characteristics	Duration of cycle, hours			
	8	6	4,5	3
Duration of periods, hours:				
Heating	6	4	3	2
Cooling	2	2	1.5	1
Gas consumption, nm^3/hour	60500	57000	58200	55500
Calorific value of gas, kcal/nm^3	947	960	945	940
Flue gas temperature, °C:				
At commencement of heating	170	170	160	150
At end of heating	450	390	350	270
	310	280	255	210
Blast consumption, nm^3/min	2604	2618	2597	2586
Temperature, °C				
Cold blast	80	120	65	90
Hot blast	850	850	850	840
Humidity of blast, g/nm^3	30.2	30.2	30.2	30.2
Heat content of 1 nm^3 of cold blast, kcal	24.8	37.3	20.2	27.9
Heat content of 1 nm^3 of hot blast, kcal	286.5	286.5	286.5	284.3
Heat content of steam at the cold blast temperature, kcal/kg °C	0.4472	0,4474	0.4471	0,4473
The same at the hot-blast temperature, kcal/kg°C	0,4997	0.4997	0,4997	0.4997
Calculation of efficiency				
From combustion of the gas, millions of kcal	57.4	54.7	55.0	52.2
Physical heat of the gas and air, millions of kcal	1.148	1.094	1.100	1.044
Heat expended on heating the hot-blast stoves, millions of kcal	58.548	55.794	56.100	53 244
Quantity of blast, thousands of nm^3/h	156.240	157.080	155.820	155.160
Heat expended on heating the air, millions of kcal	40.8	39.2	41.3	39.8
Quantity of steam in blast, kg	4720	4750	4675	4670
Heat expended on heating the steam, millions of kcal	1.836	1.765	1.814	1.783
Total heat expended on heating the blast, millions of kcal	42.636	40.965	43.114	41.583
Efficiency of hot-blast stoves, %	72.8	73.5	76.8	78.3

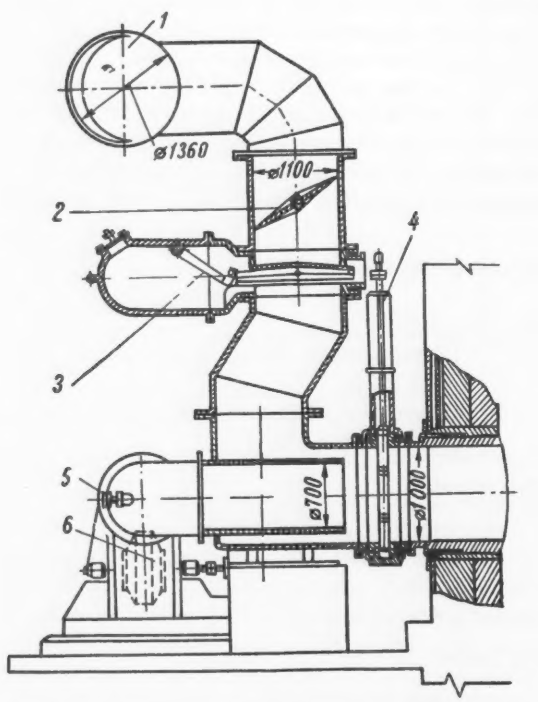

Fig. 2. Gas burner. 1) Clean gas main; 2) gas-regulating butterfly valve; 3) gas cut-off valve; 4) isolating slide; 5) photocell; 6) fan.

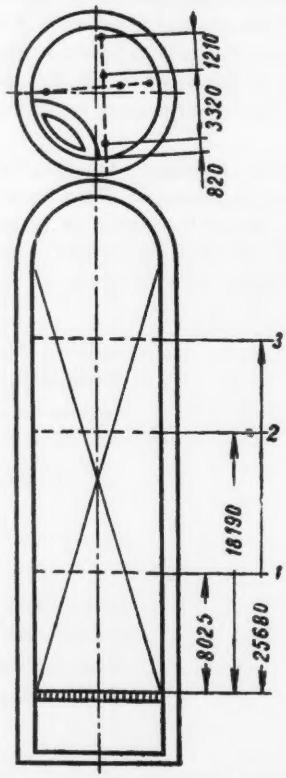

Fig. 3. Diagram showing place of thermocouples in checkerwork of hot-blast stove: 1,2,3) levels.

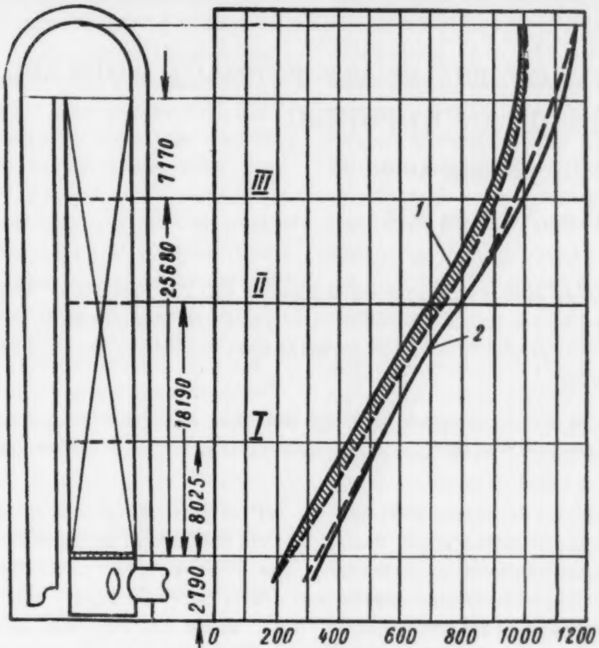

Fig. 4. Variation in checkerwork temperature vertically during heating period: 1) For three-hour cycle; 2) for two-hour cycle; I, II, III) levels.

ly being introduced. As is known, with increase in the hot-blast temperature, the efficiency of the hot-blast stove falls. For a quantity of blast of 2500 nm^3/min and a temperature of 900°C, the efficiency of the hot-blast stoves has currently fallen to 71%. At the same time, the final temperature of the escaping products of combustion is 320°C.

In practice, with increase in the hot-blast temperature, it is also desirable to have a high hot-blast stove efficiency. For this reason, the operation of hot-blast stoves on three-hour and two-hour cycles has been investigated at the Kursk Metallurgical Combine. The number of three-hour cycle heating experiments was 192, and that of two-hour cycle experiments was 540. In the two-hour cycle, the duration of the air period was 40 min.

The experiments showed that when the hot-blast stoves were operated on a two-hour cycle, the efficiency increased by 3.4%, the temperature of the escaping products of combustion fell by 30°C and the gas consumption was reduced by 0.5 thousand m^3/hr.

Thus, reduction in the duration of the cycle with increase in the hot-blast temperature increases the efficiency of the hot-blast stoves.

When these experiments were carried out, a study was made of the vertical temperature distribution in the checkerwork as a function of the duration of the cycle. For this purpose, 18 chromel-alumel thermocouples were placed in the checkerwork of one of the hot-blast stoves at three different levels above the checkerwork base grating (Fig. 3). The readings of the thermocouples were recorded by a recording potentiometer for three-hour and two-hour cycles. As will be seen from Fig. 4, no particular differences in temperature distribution were found for the upper and middle rows of the checkerwork; the shift of the curve for the checkerwork bottom in the case of the two-hour cycle is due to the reduction in the final temperature of the products of combustion. There is a substantial difference in the temperature distribution at the commencement of heating (or at the end of the air period). The temperature curve for the end of the air period for the two-hour cycle is shifted to the right in relation to the corresponding curve for the three-hour cycle. The area formed between these curves (it is shaded in Fig. 4) represents none other than the quantity of heat which may be utilized in the blast furnace. Consequently, operation of the hot-blast stoves on a two-hour cycle may be utilized not only for increasing the efficiency, but also for increasing the hot-blast temperature.

THE ACHIEVEMENTS OF THE BLAST-FURNACE WORKERS OF THE CHINESE PEOPLE'S REPUBLIC

Li Kung-ta and Lin Tsung-ts'a

Translated from Metallurg, No. 4, pp. 9-13,
April, 1960

An abbreviated translation of an article by Comrades Li Kung-ta and Lin Tsung-ts'a "The achievements of the blast-furnace workers of the Chinese People's Republic in 10 years" which appeared in the Chinese journal "Steel and Cast Iron" (1959, No. 18) is printed below. The material from this article has been supplemented by information from other Chinese sources.

The full translation of the article was made by Wang Wên-tsun, Ai K'uei-sheng, F'ung-Hua-tung and Tsui Shu-chu, students at the Dnepropetrovsk Metallurgical Institute. I. P. Semik, a lecturer, acted as editor.

In China, metallurgy has been developed from the earliest times. However, because of the weight of feudalism and imperalism, its development took place slowly. Only in 1890 was the first modern blast-furnace constructed (in Hanyang). Subsequently a few more metallurgical factories were put up, but the rate of growth of production was low. The maximum yearly output of pig-iron before the liberation of the country reached 1.8 million tons, in 1943.

After the victory over Japan in 1945, the reactionary Kuomintang regime not only failed to develop the metallurgical industry, but even wrecked factories which were working. As a result of this, production of pig-iron fell to 251 thousand tons in 1949.

It was only after the liberation of the country that Chinese metallurgy began its rapid development.

In the years 1949-1952, mainly repair and reconstruction of old factories in particular the Anshan Metallurgical Combine (AMK), were carried out.

Chinese metallurgists began to make wide use of the progressive methods of the Soviet Union and achieved great successes; in 1952, 1.92 million tons of pig-iron were smelted, with an average productivity (measured by the furnace volume in m^3 required to produce 1 ton of iron per day) for the year, in the country, of 0.975 (instead of 1.62 in 1949).

During the first five-year plan (1953-1957) the construction of two new metallurgical centers was started at Wuhan and Paotow, whose large blast furnaces are supplied with the most modern equipment. In the five-year period 82 blast furnaces were built or reconstructed, the total volume of all the furnaces in the country rose from 5172 m^3 in 1952 to 15,735 m^3 in 1957. Thus, even in 1956 it became possible to exceed the pig-iron production set by the five-year plan for the subsequent year. The average annual productivity for the whole country stood at 0.766. In the next year of the first five-year plan 5.94 million tons of pig-iron were smelted with an average productivity for the year for the country of 0.757. The best figures were obtained at the AMK, where the average productivity for 1957 was 0.71 with a coke consumption of 711 kg/ton and in Dai (productivity 0.696).

In the first five-year plan, knowledge of advanced Soviet methods was obtained and disseminated; namely, the regulation of furnace working "from above", working with blast of constant humidity, the use of self-fluxing sinter, improvement of charge preparation and so on.

1958 was the year of the "great leap forward".* In keeping with the general party line, a massive "drive for iron and steel" was started, as a result of which thousands of small furnaces were set up for smelting iron. This improved the distribution of the iron and steel industry throughout the regions of the country. In the same year two very large blast furnaces† (at Wuhan and Anshan) were started up.

Because of the introduction of advanced methods of operation, the working details of the furnaces were markedly improved.

The smelting technique for iron was being perfected up to 1958, but because of frequent breakdowns in the optimum relationship between the gas-permeability of the charge and the amount of blast, hanging began to occur in many furnaces in the years 1953-1954. The idea, therefore, spread that it was not desirable to raise the daily coke combustion rate above 1.1 tons/m^3 for large furnaces and 1.2 tons/m^3 for small ones since by doing so scaffolding of the charge and hanging would certainly take place.

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*According to a report in the magazine "Friendship" (1959, No. 42, p. 11) in 1958, 13.69 million tons of pig-iron were smelted in China, including good quality pig-iron smelted in small furnaces; this is 2.28 times greater than the 1957 figure. 9.53 million tons were smelted by modern methods, which is 1.6 times greater than the previous year's production. Editor.

†Furnace volumes 1386 and 1513 m^3 respectively—Editor.

In the first five-year plan much attention was paid to achieving stable, uniform furnace working and to reducing coke consumption. In this respect Chinese blast-furnace workers achieved considerable successes. On No. 4,6, and 7 blast furnaces at AMK in November 1957, the figures for coke consumption per ton of iron were 658, 682, and 678 kg respectively. But the volume coke combustion rate did not increase further.

In 1958 the blast-furnace workers of the CPR, inspired by the massive "drive for iron and steel" surpassed figures for melting production which had formerly been considered unattainable. Thus, on large volume furnaces (around 1000 m^3) the melting rate was raised to 1.3–1.4 tons/m^3, on medium sized furnaces (300-500 m^3) to more than 1.4 tons/m^3, and on furnaces with a volume less than 55 m^3 to 1.8 tons/m^3. The productivity was markedly improved. In this respect, especially remarkable success was achieved in the factories at Penhsi and Taiyuan, where the productivity stood at 0.666–0.625 in the first half of 1958, and reached 0.55 and 0.46 at Taiyuan and Penhsi respectively in the last quarter of the same year. The ratio of ore charge to coke in furnaces with volumes around 1000 m^3 rose to 2.9–3.0.

In 1959, the working figures continued to improve. In Penhsi, the productivity reached 0.411 in May 1959, and the consumption of coke was correspondingly reduced to 656 kg/ton. On No. 3 furnace at AMK, from January to May 1959 the productivity improved from 0.594 to 0.46, and the consumption of coke was reduced from 772 to 638 kg/ton.

It should be emphasized that in keeping to uniform furnace working the rate of coke combustion is also markedly raised. Thus, in the Penhsi plant in the fourth quarter of 1958, the figure was 1.4 tons/m^3, and in April to May 1959, 1.55 tons/m^3. In No. 1 Furnace at the Taiyuan factory the corresponding rates were 1.45 and 1.51 tons/m^3, and in No. 9 furnace at AMK, 1.327 and 1.38 tons/m^3.

At the same time as the increase in the coke rate, the blast temperature was also raised, bringing it to 900-1000°C. Much practical experience has been gained on maintaining uniform furnace working at high melting rates.

In this way, the achievements in blast-furnace production in the ten years is expressed not only in the increase in the amount of pig-iron smelted, but also in the improvement in the technical and economic details of the process (Table 1).

The vigorous expansion of blast-furnace production in China is intimately connected with the strengthening of planning and building organizations. Standard plans for furnaces with working volumes of 3, 8, 13, 55, 100, 255, 620, 1053, and 1513 m^3 have been prepared, all the equipment for which can be prepared in Chinese factories. A blast-furnace with a volume of 1513 m^3 was constructed in 4 months.

The Development of Pig-Iron Production in Small Furnaces

As a result of the massive "drive for iron and steel" which sprang up in 1958, a very large number of small blast furnaces were constructed in a short time. By September 1959 the total volume of small (6.5 to 100 m^3) furnaces working reached 43,000 m^3, which is almost twice the total volume of modern furnaces in China.

About 10 million tons of pig-iron were smelted in small blast furnaces in 1959 and in all the second five-year plan about 55 million tons will have been smelted. Starting from 1963 the annual production will exceed 15 million tons.

In this way, by adopting the party policy of "going as fast as possible" it will have been possible to obtain 55 million tons of pig-iron in a short space of time without large capital investments: this is playing, and will play a large part in creating the most important requisite for the further leap ahead of all the national economy of the country.

Work on a large number of small blast furnaces also makes it possible to train hundreds of thousand of metal-workers, who will have obtained practical working experience and raised the whole level of socialist consciousness; this is very important for the further development of metallurgy in China.

From the spring of 1958 "more or less home-made" small furnaces began gradually to be replaced by "more or less modern" ones. This made it possible to improve the quality of iron and to increase the amount smelted.

TABLE 1. Production of Pig-Iron in the Chinese People's Republic

Year	Production, % of 1943 figure	Furnace volume, % of 1949 fig.	Productivity*		Relative coke consump.
			tons/m^3	m^3/ton	
1943	100.0				
1949	13.49	100.0	0.617	1.62	
1952	106.80	183.0	1.024	0.975	
1953	124.0	247.0	1.035	0.965	1.008
1954	173.0	334.0	1.080	0.925	0.916
1955	215.0	387.0	1.150	0.870	0.876
1956	268.8	450.0	1.305	0.766	0.808
1957	333.0	587.0	1.321	0.757	
1958	755.0**		1.505	0.665	0.713

*From September 1958, in China the productivity has been reckoned as the daily tonnage of iron smelted for each cubic meter of useful furnace volume. In the original article the productivity was presented for all the years as tons/m^3. Here, for the convenience of Soviet readers, as well as the original figures for productivity, the productivity is given in USSR units–m^3/ton.

**Pig-iron smelted in small furnaces is not entered here; this, because of its poor quality, is not suitable for conversion to steel and is therefore not included in the fulfillment of the state plan. Its amount is 4-5 million tons.

By October 1959 the proportion of good quality iron exceeded 75% of all that smelted in small furnaces for the country as a whole.

The use of small blast-furnaces made it possible to carry out a number of experiments in improving the preparation of the charge, in using a large blast volume and raising its temperature, in using recuperative air pre-heaters and rammed carbon refractory lining, and in replacing limestone by calcined lime.

At the Limin' Factory in Hunan Province, a blast furnace with a volume of 7 m^3 worked in November 1958 with a productivity of less than 0.278 m^3/ton. At Yusen factory in the same province the blast is being heated with recuperators to 650-700°C, although it had formerly been considered that it was impossible to heat blast above 550°C by this method.

At the Tanshan factory, as a result of replacing limestone by lime, the production capacity of a 13 m^3 blast furnace was increased by 67%, and the consumption of coke was reduced by 37%. For small furnaces this measure is especially important because they usually run on poor ores from deposits of local importance and therefore a large amount of flux is used. The use of lime, because of the considerable saving in coke consumption and the reduction in the amount of sulphur thereby introduced, also improves the quality of the iron.

For small furnaces a charge consisting of small lumps of uniform size must be used. When, for example, coke with a lump-size of 5-20 mm was used in a 7 m^3 furnace, it ran uniformly, the blast-volume per minute was six times the furnace volume and in all it was clear that the blast volume could have been increased still further if the air-pipes had permitted. If the lump size of the ore exceeded 20 mm the furnace could not pre-heat the ore burden, the hearth grew cold and production capacity was reduced.

The length of small furnace campaigns is quite adequate. For example, one at the Khĕtsuan factory has already been working for four years without major repair. Experience indicated that small blast furnaces fully justify themselves. If the coke consumption is reduced, pig-iron smelted in them is not inferior in quality to iron from modern blast furnaces.

Boosting Blast-Furnace Melting

As has been remarked above, in recent years the volume rate of coke combustion has been markedly increased, but this has not, however, lead to hanging. The consumption of coke per ton of iron has not only not been increased, it has been substantially reduced.

As an example, average monthly figures for 1958 are shown in Table 2 for a factory in Penhsi. At the Taiyuan‡ plant and on the advanced furnaces at AMK similar results are obtained. The following are the chief reasons causing these advances.

Preparation of the Charge Materials for Melting

Experience indicates that the concept of matching blast volume to the gas permeability of the charge is sound. The better the preparation of the charge, the higher will be the optimum rate of melting and the lower the coke consumption. Without preparation of the charge it is very difficult to speed up melting and at the same time to reduce coke consumption. In the CPR various methods are therefore being used to prepare the charge.

Homogenization. Much attention is being given in many Chinese blast-furnace shops to ore homogenization. In the chief metallurgical centers the ore is homogenized throughout the entire journey from the mine to the blast-furnace shop. In the remaining factories the ore is homogenized by stacking stock piles in layers, and taking ore from across the layers on the ore stock yard of the blast-furnace shop. In the latter case the variation in the iron content of the ore is ± 1%.

Sorting According to Size. The majority of blast-furnace shops in China work with a sorted charge, which leads to uniform running of the furnace and to an increase in the ore-burden.

‡Figures for the Taiyuan plant were published in Metallurg, No. 1 (1960). [see English translation]

TABLE 2. Average Monthly Blast-Furnace Melting Figures at the Penhsi Plant for 1958
*(Average for Four Furnaces)**

Detail	Months, 1958											
	I	II	III	IV	V	V	VII	VIII	IX	X	XI	XII
Productivity tons/m^3	1.312	1.435	1.447	1.551	1.786	1.825	1.884	1.934	2.077	2.245	2.139	2.265
Productivity m^3/ton	0.762	0.697	0.691	0.644	0.560	0.548	0.530	0.516	0.481	0.445	0.467	0.441
Volume rate of melting, tons of coke per day per cubic meter of furnace volume	0.996	1.015	1.029	1.066	1.175	1.225	1.248	1.326	1.335	1.399	1.437	1.394
Coke consumption, tons per ton of iron	0.766	0.717	0.714	0.692	0.662	0.690	0.663	0.677	0.638	0.627	0.707	0.656

*This table is not taken from the edited article, but from another published in a more recent number of the same journal (1959, No. 13, p. 509). In the original, productivity was given in tons/m^3. The figures in the second row were added by us for the convenience of Soviet readers.

Sifting out the fraction less than 5 mm from the sinter resulted, in the first blast-furnace shop of the Penshi plant, in an increase of 15% in production capacity, but in both shops of the plant, on the average, the increase in production capacity was 6-8% and the reduction in coke consumption 4% (medium volume furnaces are worked in the first shop, and large volume furnaces in the second). Sorting coke according to size and charging the various fractions separately in 1959 resulted in an increase of production capacity of 6-8% in the first shop.

Self-fluxing of the Sinter. At many plants and in research institutes in China important investigations are being carried out to improve the quality of the self-fluxing sinter, which has made it possible to reduce its basicity to 1.0-1.2 and in the first blast-furnace shop at Penhsi to 1.6.

In the first years after the liberation of the country the basicity of the sinter did not exceed 0.5; it contained large amounts of fines. For a long time there was no success in rendering it compact, since the sinter-burden was coarse-grained, and the consumption of coke breeze was high. This lead to a highly fused weak sinter being obtained. By the end of 1957, at all the country's sinter-plants, a method of obtaining a compact self-fluxing sinter had been evolved.

Raising the sinter basicity improved blast-furnace melting figures. For example, at Anshan with a charge containing 60% sinter, when the sinter basicity was increased from 0.6 to 1.0 the consumption of the limestone in the blast-furnace charge was reduced by 60-70 kg/ton of pig-iron, the consumption of coke was reduced by 4-5%, the productivity improved by 5-7%, the working of the furnace became more uniform and the quality of the pig-iron was improved.

In the first blast-furnace shop at Penhsi, by working with a charge containing 95% of highly basic sinter, consumption of limestone was reduced to 15 kg per ton of pig-iron.

At Penhsi and Anshan they have begun to add limestone containing dolomite to the sinter-charge, to bring the MgO content in the sinter to 2-2.4%; this has improved both the first-stage slag-formation in blast-furnaces and the gas-permeability of the burden column. This measure has now spread to all the plants in the country. The experience at the Penhsi, where 100% sinter is now used in the charge (except manganese ore), showed that increasing the proportion of sinter in the charge gave, for each 10% above 35%, an increase in production capacity of 1.6-2.4% and a reduction in coke consumption of 1.7-2.7%.

Use of Granules. In 1958 an investigation which yielded good results was carried out at Anshan to produce granules. In the same year the first installation for the production of granules went into service in China. The production capacity of the plate-like granulator is 1.7-2.0 tons/hr·m^2, and the production capacity of the pre-heating furnace is 42.42 tons/hr. The quality of the granules is very high; basicity up to 1.2 and more; yield of fines, less than 5 mm in size after screening, is 11.9%; the quantity of fines in the finished product is small; and the transportability is good.

The use of granules as 50% of the charge in No. 2 blast-furnace in this factory has lead to a 7% increase in productivity and to a 7% reduction in coke consumption.

From April 1959 in a number of factories in the Shandun province spherical briquettes have been successfully produced in a roll-press from local fine ore. The cost of producing these is 60% less than the cost of producing sinter. Experience showed that, when small furnaces (from 3 to 28 m^3 in volume) were worked with 100% of the charge made up of these briquettes, the production capacity was increased as compared with sinter-working, the coke consumption was reduced and the quality of the pig-iron improved.

Improving the quality of the ore. Raising the iron content of ores reduced the output of slag and consequently improved gas-permeability in the zone of slag-formation, reduced the coke consumption and raised the furnace production capacity.

At the Penhsi metallurgical plant the iron content in the concentrate was raised from 60% in April to 66% in December 1958. For some time, the iron content in the self-fluxing sinter at the Anshan metallurgical combine has been raised from 50 to 54% which of course, counts in the improvement of blast-furnace productivity noted above.

Improving the Quality of the Coke. At the Taiyuan plant, from January to December 1958, that is, in the period of greatest intensification of furnace working, the ash content of the coke was reduced from 10.97 to 9.78%, and the sulfur content from 0.875 to 0.485% with a drum sample of 320 to 340 kg. The coke quality was also improved at the Shichingshan plant.**

Regulating Furnace Running "From Above". The wide application of this method even before 1958 resulted in a considerable improvement in melting figures. Thus, because of its use at AMK, furnace production capacity was increased by 34%, coke consumption was reduced from 1.04 to 0.799 tons/ton, the carbon dioxide content in blast-furnace gas was raised from 8.3 to 10.8%, the average amount of scaffolding was reduced from 0.7 to 0.3 per day. On No. 2 furnace at the Taiyuan works, regulation "from above" raised production capacity by 23%.

In 1958 the blast-furnace workers of China achieved new successes in this field. At the plants in Penhsi and Taiyuan they secured the efficient distribution of the gas stream by regulation both from "above" and "below".

At the Penhsi plant, with stepped-up melting, the distribution of the gas stream across the cross section of

**However, at the Penhsi works where the furnaces are driven harder, coke quality is poorer: ash content, 13.5-13.8%; sulfur content, 0.75-0.85%; drum sample about 305 Kg. Editor.

TABLE 3. Change in Average Blast Temperature and Corresponding Coke Consumption in Two Factories from 1952 to 1958.

Factory	Detail	Year						
		1952	1953	1954	1955	1956	1957	1958
Anshan Metallurgical Combine	Average blast temp., °C	590	671	653	763	857	860	More than 900
	Coke consumption, kg/ton	881	918	920	851	737	711	655
Penhsi Metallurgical Plant	Average blast temp., °C	698	667	683	780	810	825	More than 900
	Coke consumption, kg/ton	804	807	774	755	823	845	685

TABLE 4. Working Figures for One of the Furnaces at AMK in 1958

Month in 1958	Productivity		Coke rate, tons/m^3	Coke consump., tons/ton of iron	Sinter content of charge, %	Throat pressure, atm.	Blast temp., °C
	m/m^3	m^3/m					
February	1.408	0.710	1.033	0.709	88	0.6	816
June	1.672	0.597	1.142	0.672	100	0.4	821
November	1.859	0.538	1.351	0.705	100	0.8	806

the stack was improved as a result of a change in the charging system. But with very high driving rates, regulation "from above" no longer gives appreciable action. Regulation "from below" is then used. On No. 2 furnace, at this plant, the tuyere diameter was increased from 120 to 180 mm, which resulted in an improvement in the distribution of the gas-current; as a result, the melting rate was successfully increased from 1.338 to 1.542 tons/m^3.

On No. 1 furnace at Taiyuan, by regulating the running of the furnace charging system (working "with coke first") and by gradually increasing the content of self-fluxing sinter in the charge, the melting rate was increased to more than 1.4 tons/m^3, the coke consumption being reduced at the same time.

The use of this advanced method in other factories has also given good results.

Increasing the Blast Volume. The improvement in the preparation of charge materials and the use of regulation "from above" have considerably improved the gas-permeability of the column of materials in the furnace, and this has made it possible to increase blast consumption. Because of this, melting rates have been markedly raised (by 30-40% or more).

At Penhsi, without interrupting the uniform running of the furnace, and with satisfactory technical and economic working details, up to 3.2-3.4 m^3 of blast are now used each minute per cubic meter of furnace working volume.

Blast Temperature and Humidification

In Table 3 figures are given which typify the increase in blast temperature and the reduction in coke consumption for a number of years at two large plants.

At present, in China, the blast temperature in large and average-sized furnaces is, as a rule, not less than 850°C., and the moisture content 20-25 g/m^3. In certain advanced shops the average blast temperature is 1000°C or more. At the Shichingshan plant, after reconstruction of the air pre-heaters, a blast temperature of 1080°C has already been reached.

However, these achievements do not satisfy the Chinese blast-furnace workers.

Closely connected with the increase in temperature is blast humidification, which has been widely used in China since 1954. This method is used to regulate the heat content of the furnace; it makes it possible to hold the blast temperature constant and high.

The greatest effect from blast humidification has been obtained at the Penhsi plant, where scaffoldings of the charge have been markedly reduced, furnace production capacity has been increased by 39.6% and coke consumption reduced by 38.9%. To sum up, these achievements are connected both with the improvement in preparation of charge materials and with the increased skill of attendant personnel, but the chief part has been played by the use of high temperature blast and the blast humidification.

Increasing Pressure at the Furnace Throat.

In China, the first furnace was converted to high pressure in 1956. At present, five such furnaces are already working. No. 1 furnace at the Wuhan Metallurgical Combine works with a throat pressure of 1.4 atm.

In Table 4, working figures are shown for one of the AMK furnaces, which had been converted to work with an increased blast-furnace gas pressure.

As can be seen from this table, from February to November the production capacity of the furnace rose by 30%: the increased gas pressure contributed to this.

In the summer and fall of 1959 on two furnaces at AMK working with increased pressure, the furnace volume per ton of iron produced each day, continously, stayed below 0.5 m^3/ton. On one of the furnaces of the Penhsi

plant, after conversion to high pressure,working in the third quarter of 1958 the production capacity rose by 7.6% and the coke consumption was reduced by 4.5% as compared with figures for the same furnace working at ordinary pressures. Dust removal was reduced.

Experience has convincingly demonstrated that working with increased gas pressure is an effective method of stepping-up blast-furnace melting. It will therefore have to be more widely used in the future.

Plant Improvement. Stepping up furnace operation brings out any defects in mechanical equipment: the inadequate capacity of skip hoist equipment, of casting machines, of pieces of equipment on the casting floor and so on. In 1958,in a number of factories,these insufficiences were removed and now they do not impede the stepped-up rate of furnace working. At the Penhsi plant, moreover, equipment has been installed for sinter screening and coke sorting.

Reduction of Lost Time on Blast-Furnaces.

Chinese blast-furnace workers have achieved marked successes in reducing lost time. For example, at the largest plant—Anshan—the working time on the furnaces as a proportion of the actual calendar period elapsed was: in 1950, 96.57%; in 1956, 99.27%; and at present it has reached 99.76%.

Editors additions and notes. Regretably, in the edited article,no figures are given about the charge composition for the furnaces working at the highest rates, and in particular, there are no figures about the consumption of metallic additions. A section on these figures, collected from other surces, is therefore being included.

At Penhsi in August 1958, when the average monthly productivity stood at 0.516 m^3/ton (Table 2), the charge consisted almost entirely of self-fluxing sinter with an average iron content of 53.67%. For the month, the average consumption of this was 1.85 tons per ton of pig-iron. In this way, the amount of iron thereby introduced per ton of pig-iron stood at 1850 × 0.5367=995 kg. From this it is seen that no metal addition went into the charge, or if it did, then in very small quantities.

At Penhsi,in August 1959,the average composition of the sinter being used in two large furnaces (917 m^3) was the following, in percent;

Fe	FeO	SiO_2	CaO	MgO	Yield of fractions less than 5 mm after screening	Content of fines less than 3mm
52.59	15.64	9.00	11.26	3.53	19.36	4.10

The coke contained 3.08% moisture, 0.97%volatiles, 13.49% ash and 0.75% sulfur.

Average performance in the same month for two furnaces in this shop are shown in Table 5.

TABLE 5. Working Figures for Furnaces of the Second Blast-Furnace Shop at the Penhsi Plant

Furnace	Productivity, m^3/ton	Coke consump tons/ton of iron	Coke rate, tons/m^3	Metal additions, kg/ton of pig-iron	Slag yield, kg/ton	Blast temperature, °C	Sinter content of charge, including 10% granules, %
1	0.524	0.675	1.29	20.6	518	958	99.52
2	0.497	0.606	1.22	66.7	503	1011	100.0

TABLE 6. Working Figures for Furnaces of the First Blast-Furnace Shop at the Penhsi Plant

Furnace	Productivity, m^3/ton	Coke consump. tons/ton of pig-iron	Coke rate, tons/m^3	Metal additions, kg/ton of pig-iron	Slag yield, kg/ton	Blast temperature, °C	% Fe in sinter
1	0.425	0.700	1.644	49	561	778	53.22
2	0.435	0.676	1.555	18	542	975	53.59

Figures for two smaller blast-furnaces of the same combine in the same month and working with approximately the same raw material conditions are shown in Table 6.

When it is considered that the metal addition consists of reject iron from other furnaces, and on this basis the metal addition is deducted from the amount of pig-iron smelted, then in this case the productivity of the large furnaces is 0.534-0.5333 and of the small furnaces 0.446 and 0.444. Approximately the same figures were also obtained for other months in 1959, when metal additions were small (not larger, but even smaller than in August). When metal additions were larger, melting details correspondingly improved. Thus, on a furnace with a volume of 333 m^3 the metal addition averaged 176 kg per ton of pig-iron in September 1959, and the average productivity for the month was 0.352. If the production is reduced by 17.6%, that is, the metal additions are deducted, then the productivity is 0.352 × 0.824=0.428.

On a furnace of 917 m^3 volume, the average daily productivity for October 1959 was 0.45 with a coke consumption of 574 and a metal addition of 124 kg per ton of pig-iron. After deducting the metal additions, the productivity is nevertheless 0.514.

In China now it is possible to hear the remark: "Blast-furnace practice at Penhsi has outstripped theory." Nevertheless, one cannot agree with this statement. The theory of the blast-furnace process, at any rate in the opinion of many Soviet authors, has for a long time indicated that

still greater driving rates are fully possible and that this does not upset the course of all the physicochemical changes in the blast-furnace. The driving rate is limited only by the gas-dynamic factor, and by improving the preparation of the charge for melting, or by other measures, it is possible to create the optimum conditions necessary for the gas stream—thus improving the melting figures.

To judge from the contents of the article reviewed, Chinese blast-furnace workers, by working creatively, have traveled in just this direction so that it will very truly be said "Blast-furnace workers who do not reach such melting figures as are obtained at Penhsi, are falling short of those possibilities to which the theory of the blast-furnace process has for so long pointed".

IMPROVING THE ORGANIZATION AND CONTROL OF THE FLAME IN GAS-FIRED OPEN-HEARTH FURNACES

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Chelyabinsk Metallurgical Plant
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Observations on the behavior of open-hearth furnaces show that increased heat flow to the bath may be obtained by improving the organization of the flame. A flame is considered to be well organized when its hot luminous products travel at a high speed over the surface of the bath without eddying or branching.

The principal factors affecting the organizations of the flame are the direction and velocity of the gas flow. The air flow, however, also affects the organization of the flame to a considerable degree.

It is much more difficult to alter the direction of the gas flow than that of the air flow. As a rule, deviation of the gas flow occurs as the result of incorrect maintenance of the furnace end, and therefore, in practice as there are no barriers in the path of the gas, the flame is controlled by varying the direction of the air flow by modifying the form of the wing walls.

The flame is adjusted with special care in furnaces which have Dinas roofs, where normal working of the furnace is impossible without proper organization of the flame. In furnaces which have basic roofs such adjustment is rarely made, although a badly organized flame appreciably impairs the working of the furnace.

The characteristics of the 185-ton open-hearth furnaces at the Chelyabinsk Metallurgical Plant resemble those of the same furnaces at other plants. The furnaces are equipped with Venturi port ends (Fig. 1), in which the air flows around the gas on three sides.

In most plants, the wing walls are made in the form of a smooth transition from the vertical to the slope. Such a transition produces no violent eddying of the air flow or distortion of the gas flow. In a furnace end of this type, an increase in the air flow on one side of the furnace end displaces the flame towards the opposite side. It is as if the air flow creates a pressure on the gas flow, increases the combustion zone on that side and displaces the flame towards the opposite side.

The velocity of the air is approximately one-third that of the gas, and therefore the influence of the air flow on the gas flow is not great. Investigations made at a number of plants have shown that the deflection of the flame is mainly due to the formation of a transparent flame on the side on which there is increased air supply, and the displacement of the visible part of the flame towards the opposite side.

In the course of a campaign, however, because of poor maintenance of the port end, and sometimes in new furnaces, the wing walls have the form of a steep step, projecting considerably into the furnace (Fig. 2b). With such wing walls, the air flow acts on the gas flow differently in each individual case.

In the case of built-up wing walls projecting considerably into the furnace, an increase in the air flow on one side results in a deflection of the flame towards that side. The air flow is then directed above the gas flow and passes over to the other side of the flame.

Such a condition of the wing walls is unsatisfactory, since it has a negative effect on the thermal working of the furnace: the zone of maximum temperatures moves away from the bath, and the flame produced is long and has no tip. If one of the wing walls in the furnace is built up, which often happens in machine-repairing of the corners, the flame, as a rule, is shifted towards the built-up corner. To equalize the flame, the wing wall must be diminished and restored to its original condition. Such flame correction has been repeatedly carried out in the furnaces of the Chelyabinsk Metallurgical Plant and has given positive results every time. A mixture of 50% scale, 40% quartz sand and 10% aluminum powder is used for scouring the built-up wing wall.

In the case of perpendicular wing walls, to deflect the flame in the required direction, the wing wall must be lowered and scoured down on the other side, since it is impossible to work with such wing walls; the air stream descends from them in the form of large eddies which distort the gas flow and so impart an unstable form to the flame.

The air distribution in the uptakes exercises some influence on the flame direction. Measurements made at our plant have shown that with a new, empty slag pocket and moderate rates of air flow, about 55-60% of the air flows through the back uptake, and correspondingly 45–40% through the front uptake. With a higher rate of air flow, the amount passing through the back uptake is increased. In the course of a campaign, however, as the slag pocket fills up, the air-flow distribution in the up-

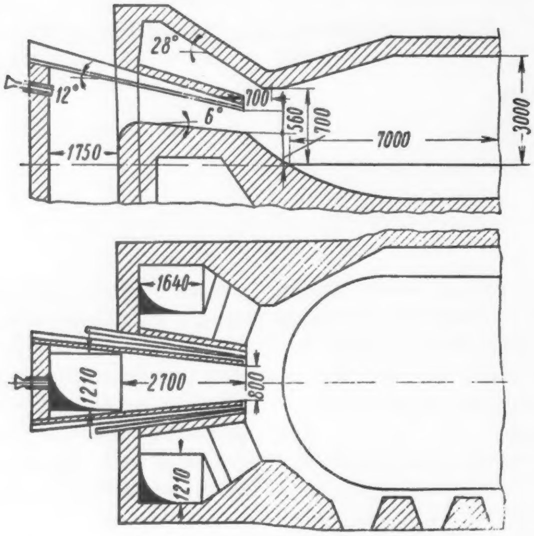

Fig. 1. Venturi furnace end,

Fig. 2. Distribution of visible flame: a) witn wing walls and slopes of good shape; b) with built-up back corner.

takes is disturbed. The position of the slag-pocket arches (for strengthening the protective walls) and of additional supporting arches (for the protection of the uptake supporting arches), etc., has a substantial effect on the air distribution in the uptakes.

The organization of the flame may be improved and its direction varied by means of compressed air or oxygen jets. Usually, compressed air is supplied by two methods: along the sides of the water-cooled gas port at the exit cross section and through the end wall of the gas port, while oxygen is supplied along the sides of the gas port. When oxygen or compressed air is supplied along the sides of the port, and the direction of the flame is to be altered the oxygen or compressed air is shut off on that side of the gas port towards which the direction of the flame is to be altered. The oxygen or compressed air jet entering at high speed then deflects the glass flow (Fig. 3).

The air jet injected through the end wall of the gas port influences the flame direction at speeds above 80-100 m/sec and a rate of flow of more than 1500 m^3/hr. The high-speed jet, during its passage through the gas port, forms a concentrated guide jet which deflects the flame in its direction (Fig. 4).

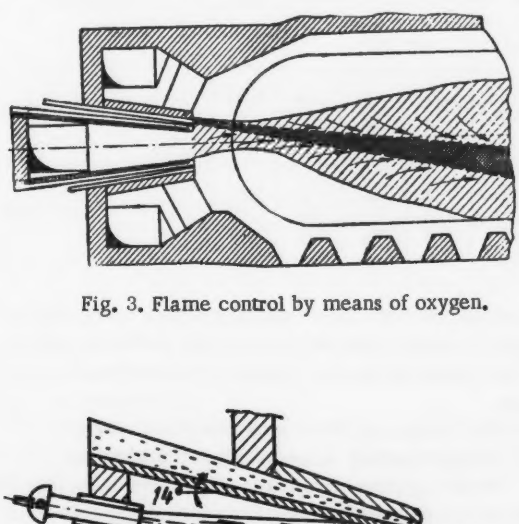

Fig. 3. Flame control by means of oxygen.

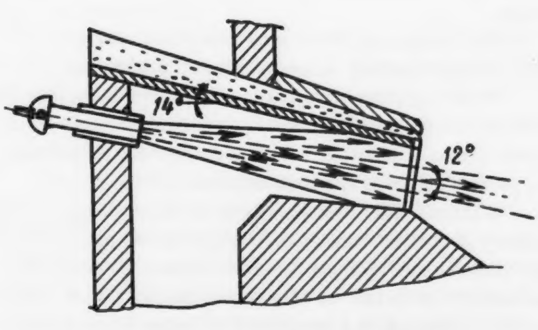

Fig. 4. Distribution of guide air jet in gas port.

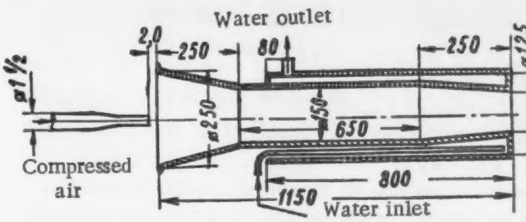

Fig. 5. Conical injector.

If, however, the air jet is deflected too sharply so that it impinges on the lining, the flame is strongly distorted on the impact side. When air is injected through the end wall of the gas port, therefore, the direction of the air jet and the character of the flame must be watched. The direction of the air jet should be altered as soon as eddies appear on one side of the flame. The best results in controlling the flame are obtained with a compressed air jet issuing at a rate of approximately 2000 m^3/hr. A jet of this type will exert an ejector effect on the gas flow and will even cause it to constrict within the port. An intense, well-organized flame then leaves the port. In such a case, the compressed air jet should be placed exactly in the center of the gas port. In practice, however, compressed air is not used, being in short supply at the plants. It is used for ejecting atmospheric air, the exit velocity of which is 60-80 m/sec.

The air jet issuing from the ejector with this velocity acts on the direction of the gas flow to a lesser degree. It is advantageous to use conical injectors (Fig. 5) for increasing the exit velocity of the air and for controlling the flame.

The slope in front of the gas port has a considerable influence on the organization of the flame. An analysis of the causes affecting the thermal working of a furnace showed that a lasting improvement is obtained if the slope is interrupted immediately after the gas-port outlet, and is then continued at the normal slope (about 20°). As it leaves the port, the gas flow then creates a partial vacuum below itself, in consequence of which hot air is drawn in underneath the flame. At the same time, the conditions for the transfer of heat from the flame are improved, since the zone of maximum flame temperature is located in the immediate vicinity of the bath.

Separation in the gas flow at the port exit is also responsible for an improvement in the thermal working of the open-hearth furnaces having furnace ends of Kursk Metallurgical Combine design (with a gap under the gas port). In this case the bulk of the hot air for the flame comes from the wing walls and the main purpose of the air gap below the gas port is to clean the bank and maintain the flow separation at the gas-port exit. This is confirmed by the fact that the high output of the furnaces was maintained in the case of flow separation at the gas port exit, even after the gap under the port had been made up. Practical experience with the furnaces of the Chelya-

binsk Metallurgical Plant has shown that with separation of flow at the gas-port exit, the output of the furnace is increased by 8 to 12 %.

In the case of a discontinuity in the slope at some distance from the gas-port, however, the effect falls off sharply and may even be negative, since the kinetic energy of the gas flow on leaving the port drops rapidly, due to reduction in velocity, and the abrupt flow separation may distort the flame.

If there is a discontinuity in the bottom inside the gas-port itself, the furnace output is also reduced, because of the increase in width of the gas stream inside the port and the abrupt drop in its energy on exit.

Build-up of the slope has the greatest effect in reducing the output of an open-hearth furnace, since the built-up slope causes the flame to spread and break up. Even with only slight build-up of the slope, a pressure head is set up below the flame, which makes it difficult for the air to penetrate under the flame. The combustion zone is located only in the upper part of the flame, thereby impairing the heat distribution between metal and roof. Considerable and abrupt build-up of the slope impairs the flame.

In practice, cases of build-up of the back corners are not infrequent, and the gas flow is then shifted towards the built-up corner, because of spreading. This can be corrected only by restoring the corner to its normal condition.

The air should meet the gas in the working space of the furnace with the least possible amount of eddying. In this connection, serious disadvantages accrue from any increase in the lining or in the dimensions of the front end of the gas port, since considerable eddying is then set up in the region where gas and air meet. Any increase in the thickness of the outer lining at the water-cooled port exit to more than one layer or in the thickness of the inner lining to more than 150 mm is extremely undesirable. In the latter case, not only is the distance between air stream and gas stream increased, but the front end surface of the port is also increased, resulting in increased heat losses.

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THE LIFE OF OPEN-HEARTH FURNACE ROOFS

N. N. Kirillova and Yu. V. Radina

Gisogneupor

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The number of open-hearth furnaces with chrome magnesite roofs was 90% of the total number at the beginning of 1959 and the metal melted in these furnaces was 96.5% of the total steel production.

When the chrome magnesite roofs were being introduced, various designs were tried: supported arch with movable skewbacks, developed by the design section of the Kuznets Combine, support suspended with rigid fastening of the skewbacks (designed by A. S. Frenkel') and support suspended with movable skewback and support springs designed by Stal'proekt.

The roofs designed by Frenkel' had the greatest advantages in operation. This particular design is now used at practically all open-hearth furnaces. At a number of plants,the roof fastening was strengthened by increasing the number of suspensions (Magnitogorsk Metallurgical Combine, Nizhnii Tagil Steel Combine, the Dzerzhinskii and Makeev Plants, etc.).

In the 185-ton and larger furnaces the chrome magnesite roofs are lined smoothly to a thickness of 460 mm. The chrome magnesite roofs are lined with bricks made at various refractory plants. Basically, the same process is used to produce chrome magnesite brick except that there are certain changes at individual plants depending on the quality of the raw material and the type of equipment.

The "Magnezit" Plant uses a special method to produce a higher quality magnesian spinel roof brick.

Table 1 gives a comparison of the physical values for chrome magnesite components of various plants. In its combination of physical values and operating properties magnesian spinel is the best industrial brick.

In recent years there has been no basic change in the quality of chrome magnesite brick. Only the properties of the Satkinsk and Kuznets Plant bricks have deteriorated somewhat due to the use of a poorer quality raw material in the charge and to a deterioration in the firing method.

The lower quality of the Satkinsk and Kuznets chrome magnesite bricks has had an unfavorable effect on the roof life of Magnitogorsk and Kuznets open-hearth furnaces (Table 2).

The longest life for the roofs at the Magnitogorsk and Kuznets Steel Combines was in 1956; the long service of the roofs made it necessary to carry out two interme-

TABLE 1. Average Values for the Quality of Chrome Magnesite Brick (for 1958)

Plant	Compressive strength, kg/cm²	Apparent porosity, %	Start of deformation, 2 kg/cm² load, °C	Thermal changes and stability at 1300°	Chemical composition, %: MgO	Chemical composition, %: Cr_2O_3
Satkinsk	440	20.4	1530	17	68.0	11.0
Zaporozh	412	16.6	1520	15	67.9	14.8
Chasov-Yarsk	401	20.5	1510	30*	69.1	15.1
Panteleimonovskii	330	18.8	1512	89*	70.7	9.9
Kuznets	547	19.2	1505	33*	71.1	9.9
Magnesian spinel brick	801	11.4	1570	8	67.5	10.9

* At 850°

TABLE 2. Values for the Roof Life of Magnitogorsk and Kuznets Open-Hearth Furnaces

Combine	Year	Life of roofs, heats: 380-ton furnace, average	380-ton furnace, maximum	185-ton furnace, average	185-ton furnace, maximum
Magnitogorsk	1956	490	561	624	697
	1957	450	526	591	733
	1958	376	482	518	581
Kuznets	1956	475	544	654	762
	1957	455	537	571	664
	1958	420	473	563	604

diate repairs on the lower structure during the furnace campaign (with cleaning of the slag pockets and the upper rows of checkers changed), thus leading to fuller use of the roof refractories.

At the Kuznets Steel Combine with comparatively constant operating conditions and with graphs plotted for the intermediate repairs on the open hearth furnaces, there was no reduction in the life of the roofs compared with 1956.

During the last three years the thermal conditions in the operation of the Magnitogorsk furnaces have become much more complicated–there has been an increase in the average weight of the heat, there have been increases in the average thermal loads and in the consumption of liquid fuel. As a result, the time of a furnace campaign has been reduced and it was no longer necessary to have two intermediate repairs on the lower structure since the state of the furnace roof after the second repair would only prolong the campaign by 50-60 heats. The number of repairs was reduced to one per campaign of the roof, which also affected the reduction in total duration of the furnace campaign.

A test in individual 400-ton Magnitogorsk furnaces on the chrome magnesite brick with high temperature roasting and magnesian spinel brick showed the possibility of increasing the roof life to 495-519 heats with two intermediate repairs on the lower structure during one campaign of the roof.

The life of ordinary chrome magnesite brick at the new 250- ton furnaces of the Magnitogorsk Metallurgical Combine does not change and averaged 628 heats during 1958 and 1959. The good roof life is combined with high output of the furnaces. This is helped by the correspondence between the basic design features of the furnaces and the size of the charge.

The operation of basic roofs at the Kuznets and Magnitogorsk Combines therefore shows that together with the quality of the roof brick the period of service of the roofs is strongly affected by the operating conditions of the open-hearth furnaces and their design features. This is supported by an analysis of roof life in furnaces of different capacity at various steel plants (Table 3).

The average life of 400-350 -ton furnace roofs is between 330 and 345 heats, whereas furnaces with a smaller capacity have a longer life: 250-ton–450 to 475

TABLE 3. Life of Roofs of Open-Hearth Furnaces Operating with Gaseous Fuel (in Heats)

Steel combines, plants	1956	1957	1958	9 month 1959
400–350 -ton furnaces				
Nizhnii Tagil	327	403	477	455
Kuznets	475	455	420	438
Magnitogorsk	490	450	376	377
Chelyabinsk	229	289	305	365
Dzerzhinskii	232	343	321	322
Kirov	382	320	278	274
"Azovstal'"	208	203	215	231
Average	340	344	327	336
250 -ton furnaces				
Magnitogorsk	534	580	629	634
Nizhnii Tagil	427	494	411	462
Alchev	452	412	432	453
Petrovskii	366	380	360	400
Average	454	448	460	473
200–185 -ton furnaces				
Magnitogorsk	624	591	518	558
"Zaporozhstal'":				
combined use of oxygen	375	463	522	546
oxygen in flare	526	497	478	—
Kuznets	654	571	563	558
Dzerzhinskii	272	386	407	447
Chelyabinsk	407	383	393	380
K. Liebknecht	517*	498*	430	447
Kirov	427	352	326	345
Average	471	472	447	483

* Furnaces operated on fuel oil

heats, and 200-185-ton—450 to 485 heats. This is tied in with the more extreme conditions of service of the refractory lining in high capacity furnaces, the operation of which differs in the high thermal loads, the longer heats, the melting of larger quantities of loose and slag-forming materials and also by the long stretch of roof. The wear in roof linings of the 400-350-ton furnaces is correspondingly greater than for smaller furnaces.

The life of the roofs in the 400-350-ton furnaces of the Nizhnii Tagil Combine and the output of these furnaces during recent years have systematically increased, reaching bettter values than similar furnaces of other plants in 1958-1959.

Thus, if the average smelting of metal at one furnace of the Nizhnii Tagil Steel Combine in 1958 is taken as 100%, then the melting in open-hearth furnaces of other plants also using oxygen can be expressed in the following way: Makeev—75%, Chelyabinsk—67%, "Azovstal' " —66%. For this reason special attention should be paid to a study of the operating conditions of the Nizhnii Tagil furnaces.

The high values for life and furnace output were obtained by improving the operating conditions of the open-hearth furnaces, by organizing the thermal conditions and improving the aerodynamics of the flare by using oxygen and compressed air.

Despite the increase in thermal loads when using oxygen, the distribution of heat in individual periods of the melting became more efficient. There was a large increase in the consumption of heat during the periods of charging and heating, when the furnace has the maximum thermal capacity, and to a smaller extent, during periods of fusion and finishing. This meant that the furnace temperatures could be evened out during the fusion periods. As a result, the conditions of service of the roofs were made more constant and their time of operation at temperatures below 1450° was considerably reduced.

A more constant temperature system of the roofs was also favored by a reduction in the hot holdups of the furnaces, especially on hearth repairs. Whereas in 1956 the holdups on hearth repairs were 2.14, in 1957 they were 1.58, in 1958 they were 0.86, and during nine months of 1959 they were 0.73% of the calendar time of furnace operation (Table 4).

The furnace holdups were reduced mainly by mechanization and the use of rapid methods of repairing and burning-in new hearths. Furthermore, there was an increase in the operating period between repairs on the hearths due to the correct alternation of heats of steels having different effects on the state of the burning-in. At the same time, the roof design was improved by increasing the rise of the roof, improving the system for fastening (by increasing the number of suspensions) and lining, introducing regular blowing of the roofs for each heat.

Forced operation of the furnaces required the use of a refractory brick with improved properties for the roof linings. Since 1957 magnesian spinel was used to line the roofs instead of the usual chrome magnesite brick, and the wear under the same conditions was less then 20%.

Like the Nizhnii Tagil furnaces, the operation of the 200-ton furnace of the "Zaporozhstal' " Plant also has higher productivity ratings. Since 1957 the roofs of these furnaces have been lined with chrome magnesite brick from the Zaporozh Refractory Plant.

The furnaces operate with combined use of oxygen to enrich the air and direct oxidation of the bath impurities. This permits a considerable reduction in the duration of the heat (the average for the nine months of 1959 was 7 hours 33 minutes). Compared with the "Zaporozhstal' " Plant the average annual production at furnaces of other plants is: Magnitogorsk and Dzerzhinskii Plants—85%, Kuznets Steel Combine—84%, Makeev—75%, Chelyabinsk—67%. During nine months of 1959, the life of roofs at the "Zaporozhstal' " Plant was 546 heats. The high roof life when the bath was blown with oxygen was not achieved immediately. When the bath was blown with oxygen in the first campaign the roof life was sharply reduced. With further improvements in the method of

TABLE 4. Data on Hot Holdups of 400-350-ton Open-Hearth Furnaces and the Duration of the Heat (Finished Campaigns)

Features	Plants					
	Nizhnii Tagil Steel Combine	Kuznets Steel Combine	Dzerzhinskii	Magnitogorsk Metallurgical Combine	Makeev	Chelyabinsk
Average duration of heat, hour-min, 1958	10—18	11—41	12—30	13—07	13—00	13—05
9 months 1959	10—10	11—30	12—24	12—45	12—40	12—56
Hot holdups, % of calendar time, 1958	4.60	3.96	6.80	4.33	6.94	9.32
9 months 1959	4.38	3.95	6.50	3.80	6.75	6.56
Including hearth repairs, 1958	0.86	0.79	2.50	1.34	3.12	3.16
9 months 1959	0.73	0.74	2.00	1.18	3.47	2.35

using oxygen, the wear of the refractory lining of the roofs was reduced and their life increased.

Nevertheless, in some plants the furnace operating features are still poor. Thus, at the Makeev Plant the open-hearth furnaces operating with combined use of oxygen are not only poorer in output than the Nizhnii Tagil furnaces but also the Magnitogorsk and Kuznets Combine furnaces which operate without oxygen.

This is mainly due to the long hot and inter-heat holdups of the furnaces which prevent the time of the heat from being reduced. Furthermore, the low output of the furnaces is linked with the poor life of the lining. The furnace life was particularly low after 1958 after conversion to operation with oxygen blowing of the bath. During nine months of 1959 the life of the roofs on the 370-ton furnaces was only 274 heats and in the 185-ton furnaces it was 345 heats.

In contrast to the "Zaporozhstal'" plant, oxygen is introduced through the rear wall to blow the bath.

In the direct oxidation of the bath with oxygen, accompanied by intensive spraying of the metal and slag and intensive formation of iron oxide, there is an increase in the wear of the whole lining and of the roof in particular. To maintain furnace life the bath should be blown according to a carefully worked out system. However, at the Makeev Plant irregularities were permitted in the oxygen and thermal systems: the blowing period was increased, blowing was used with a high content of carbon in the bath, there were cases where the furnaces operated with thermal loading much above the standard figures, especially during the finishing period. Thus, in the 370-ton furnaces the number of heats carried out with excessive thermal loadings during this period was 15.3% for the first half year of 1959 and 13.2% with excessive use of oxygen.

Furthermore, the life of the roofs was affected by changes in the temperature conditions with sharp cooling of the lining to 1300° and below during charging and repairs to the hearth, poor maintenance on the furnaces (irregular cleaning of the gas openings and blowing of the roofs), unsatisfactory quality of the roof lining or other elements (in particular, the heads) with deviation from correct dimensions and also other reasons connected with disturbances in the furnace operation.

In the Makeev furnaces this resulted in considerable wear in the roofs, reaching 1.7 in the 370-ton furnaces and 1.1 mm per heat in the 185-ton furnaces.

At the Makeev Plant there were cases where the furnaces stopped without the roof lining being completely used up. Thus, in the first half of 1959 out of nine campaigns on the 370-ton furnaces three were finished with the roof in good condition and the minimum residual thickness of the lining was 250-280 mm.

The roofs of the Makeev Plant were lined with chrome magnesite brick from the Chasov-Yarsk and Panteleimonovskii Plants and recently they have started using brick from the "Zaporozh Plant". However, the finished campaigns of the 370-ton furnaces during 1959 did not show improvements in durability, since these furnaces were stopped prematurely for cold repairs for reasons not connected with the wear in the roof.

Under the existing operating conditions, even when using improved quality roof brick, the life of roofs at the Makeev Plant is still therefore unsatisfactory.

The life of roofs at the Dzerzhinskii Plant and also the Makeev Plant and "Azovstal'" Plant is short. The furnaces operate intensively (especially the 185-ton furnace) using steam with high values to provide the best conditions for combustion of the gas and organization of the flare. By forcing the furnace operation comparatively high output can be achieved with long idle times. The service conditions of the refractory lining in open-hearth furnaces are therefore severe. This is aggravated still further by the frequent use of iron with a high content of silica and sulfur and also the use of coke oven gas which has not had the sulfur removed. During the heats dust is entrained and large amounts of iron slag are formed at high thermal loads. In addition, the schedule for tapping the heats cannot be adhered to.

All this leads to intensive wear in the furnace lining. Thus, in a number of campaigns during 280-340 heats the furnaces were worn to a residual thickness of 50-80 mm.

Low roof life was obtained in the furnaces of the "Azovstal'" Plant—and average of 215 heats during 1958. These low values are determined by the furnace design (tilting) and also the specific process for melting the steel in the conversion of phosphorus irons with the simultaneous production of phosphate slag. The furnace operate with the combined use of oxygen and the bath is blown through the rear wall.

The roofs of these furnaces are characterized by very uneven wear which means that large sections of the lining are not fully used. To ensure more efficient use of the lining and to reduce th consumption of roof components at the plants the roofs have recently been lined with 380 mm brick instead of 460 mm brick.

Two campaigns finished in 1959 showed that with the thin lining the roof wore to a smaller extent and more evenly with the same length of service of the roofs. The specific consumption of the roof components at the "Azovstal'" Plant is very high—4.0 kg/ton compared with 1.2 at Kuznets, 1.4 at Nizhnii Tagil and 1.7 kg/ton at Magnitogorsk. It is therefore very important to reduce the wear of the roof bricks for the "Azovstal'" Plant.

Short life and low operating features are exhibited by the 370-ton furnaces of the Chelyabinsk Steel Plant although recently their operation has improved due to the use of oxygen to enrich the combustion air and also due to a number of measures introduced at the plant (regularizing furnace maintenance, improving the quality of the lining, introducing systematic blowing of the checker works, alternating with washing). In three

campaigns finished in 1959 the roof life was increased on the average by 60 heats.

At Chelyabinsk they have decided to have one intermediate repair on the furnaces.

With regard to the roof this limits the campaign of the furnace operation to 350-380 heats. Under these conditions the use of magnesian spinel brick did not lead to a considerable increase in the furnace campaign although as regard wear, this brick could provide a longer service in the roof.

The analysis of open-hearth furnace operation shows that with the increasing intensification of the process and the increase in output of the furnace even the better values for average life of the roofs in 1958-1959 did not achieve the same level as those at Magnitogorsk and Kuznets in 1956.

The increase in life of open-hearth furnace roofs with further forcing of the steel melting process in connection with the more extensive use of oxygen and high caloric fuels in open-hearth production has made it necessary to considerably improve the operating properties of refractory components, in particular the roof components.

In view of experience at Nizhnii Tagil where magnesian spinel brick has given good results in the service of 380-ton furnace roofs, the production of this brick must be increased so that all large furnaces operating with oxygen and high-caloric fuels can be supplied with this brick. In the first place, the production of this brick should be expanded at the Satkinsk Plant by organizing the production of magnesian spinel components in a new department.

So that the southern steel plants can be supplied with high-resistant roof brick it is essential to organize its production in the recently started department of the Nikitovsk Combine and also at the Zaporozh Refractory Plant. A comparison of the operating figures for the furnaces of various steel plants indicates that the furnace campaign can be still further lengthened. Thus, at a number of plants the hot holdups are still considerable, the disturbances in the thermal and technological systems have not been eliminated, poor quality lining is used and the furnace maintenance is unsatisfactory. There are cases where the furnaces were stopped prematurely with the lining still not fully used up, etc.

Also important in connection with the increase in life of the roofs and increase in the furnace output is the extension of the period of service of the lower structure of the open-hearth furnaces. For this purpose it is essential to have new design solutions for the lining of the slag pockets and the development of methods for slag removal during the campaign which do not require the furnaces to be stopped for intermediate repairs and also effective methods for cleaning melting dust from the checkerworks.

* * *

AIR-COOLED STEEL-LADLE STOPPER

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In the open-hearth shop of the Stalinsk Metallurgical Plant, rimmed carbon, killed and alloy steels are tapped and bottom-poured in ingots weighing 3.4 t. The stopper is assembled with a head type SP-13 and stopper sleeves SP-8, SP-8-2 and SP-8-4 with a stopper rod diameter of 55 mm. Pouring of the metal from a 130-135 ton ladle takes from 1 hr 10 min to 1 hr 30 min.

In pouring, cases are often observed of the head or lower part of the stopper burning off, resulting in loss of metal and unsatisfactory pouring with imparied quality of the steel. This occurrence has been more often in the middle or at the end of pouring, as is shown by the table on the next page.

Thickening of the lower stopper sleeves (from 180 to 205 mm) reduced the number of unsatisfactory pourings in 1958, but did not eliminate them.

As the result of investigations made, it has been found that unsatisfactory pouring is mainly due to deformation or fracture of the lower part of the stopper rod, due to its inadequate mechanical strength at the temperatures of 1100-1300°C, to which it is heated during pouring.

When the stopper is deformed, the joints between the stopper sleeves open; molten steel enters them and melts the stopper rod. In addition, deformation of the stopper causes trouble in seating the head in the nozzle,

	1956	1957	1958
Total number of heats in which trouble occured in pouring, %	8.94	8.59	6.17
These included:			
1) Due to fracture of heads and burning of stoppers, %	7.24	5.51	3.79
Of these:			
a) On first opening	0.05	0.67	0.52
b) On the first stools	0.78	0.64	0.79
c) At end of pouring	6.41	4.20	2.48
2) With loss of metal due to fracture of head and burning of stoppers, %	1.66	1.37	1.02

which results in leakage of metal during the pouring operation.

A metallographic investigation has shown that repeated use of the stopper rod promotes the fracture of its lower part. There is a considerable increase in grain size resulting in a sharp reduction in the mechanical strength of the rod.

Air-cooled stoppers* have been developed and tested for avoiding unsatisfactory pouring due to inadequate mechanical strength of the stopper rod.

Construction of the air-cooled stopper (Fig. 1). The stopper rod is made of low-carbon steel tube 57 mm in diameter with a wall thickness of 9-11 mm. To the lower end of the tube is welded a pressed screwthreaded part (Fig. 2 , on which the stopper head is screwed. In the hollow rod a tube is inserted having an external diameter of 16 mm and an internal diameter of 12 mm, through which compressed air is supplied at a pressure of 3-4 atm from the shop mains on the pouring platform. The air consumption is 20-28 m^3/hr. Air is connected up immediately after arrival of the ladle at the pouring platform and is supplied until the end of pouring.

In passing through the space between the inner and outer tubes, the air cools the stopper rod and escapes into the atmosphere.

In the course of investigation and practical trials, the construction of the individual units of the air-cooled stopper was developed. The tube by which air is supplied to the stopper is disconnectable, one part being fixed immovably to the ladle shell and the other is inserted in the stopper after the latter has been mounted in the ladle. Figure 3 shows the construction of the disconnectable union. The flexible tube is similarly connected to the air-supply tube.

The length of the lower part of the air-supply tube permanently fixed to the ladle is 600-700 mm, thereby eliminating wear of the flexible tube due to the high temperature of the steel in the molds.

Flexible tubes for the supply of compressed air are kept in a special locker on each pouring platform.

Assembly, drying, mounting in the ladle and removal of the stoppers from the ladle are carried out in the usual order.

The operation of the air-cooled stoppers was initially investigated during the pouring of 50 heats. Forty-eight heats were poured without trouble in the working of the stoppers and without loss of metal.

During the pouring of two heats, burning of the stopper occurred for reasons not connected with the use of air cooling: in one case, the stopper burnt through at slag level before the air was connected up, due to the metal being kept in the ladle for 35 min (on account of sticking of the stopper rod head); in the second case, tapping of the heat from the furnace took 42 min and the stopper rod was heated to a considerable extent; after the air had been connected up, five bottom pouring operations were carried out normally, on the sixth pouring, part of the stopper head broke off, the air was cut off and the stopper burnt through.

To determine the efficiency of the air-cooling of the stoppers, the heating temperature of solid and cooled stoppers was measured by means of chromel-alumel thermocouples, the junctions of which were rolled into the rod at distances of 100 and 1000 mm of the head when assembling the stopper.

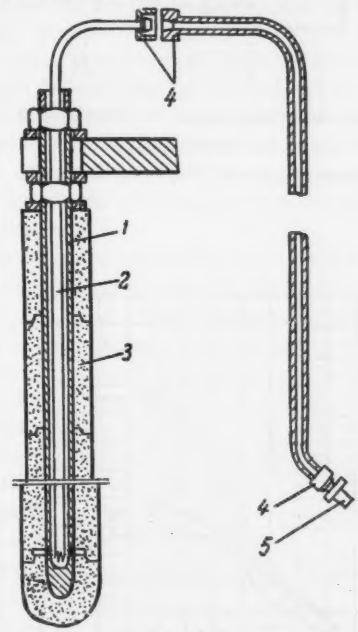


Fig. 1. Diagram of cooled stopper. 1) Tubular rod; 2) tube through which compressed air is supplied to the stopper rod; 3) refractory stopper sleeves; 4) detachable union; 5) flexible tubing.

*The following took part in the work: A. B. Ivangorodskii-Klebanov, A. N. Slin'ko, M. A. Kuritskii, V. M. Strelets, N. V. Pitak, V. G. Osipov, V. B. Evtushenko, M. S. Gordienko, A. E. Kolesnik.

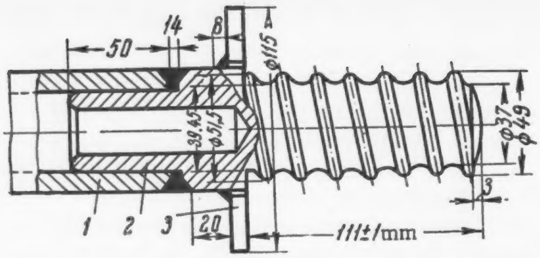


Fig. 2. Lower part of cooled stopper rod: 1) Tube of low-carbon steel; 2) pressed screwthreaded part; 3) supporting disk.

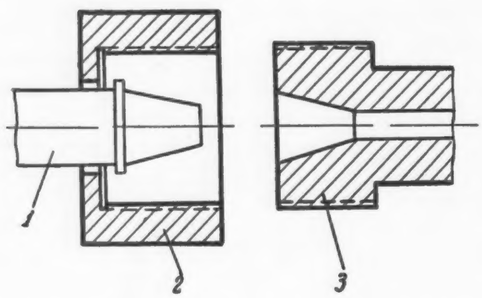


Fig. 3. Disconnectable union: 1) Tube by which compressed air is supplied to the stopper rod; 2) coupling nut; 3) connecting piece with conical recess.

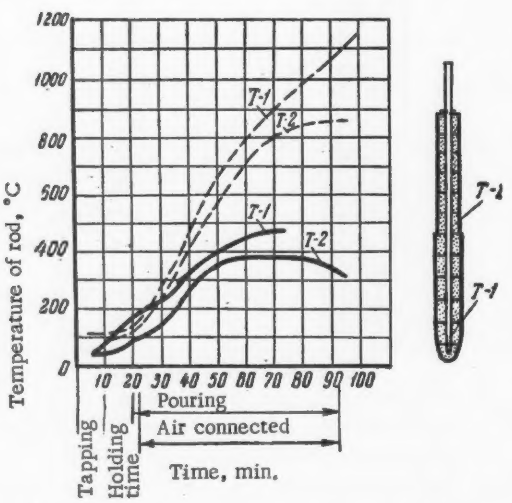


Fig. 4. Temperature variation of stopper rods: T-1, thermocouple mounted at a distance of 100 mm from top of stopper head; T-2, thermocouple mounted at a distance of 1000 mm from top of stopper heads: ------solid stopper rod; ———cooled stopper rod.

Figure 4 shows that at the end of pouring, the temperature of the solid rod at 100 mm from the head attained 1200°C, while in the case of the tubular rod, it was 500-600°C, i.e., about half as much.

After the level of the metal had fallen below the position of the thermocouple, the temperature of the cooled stopper rods fell abruptly; in the case of the solid rod, no fall in temperature was observed. In the period from the commencement of tapping to the connection of air (an average of 20-25 min) the cooled rod became heated to a temperature of 200°C. No deformation of the stoppers was observed during pouring. After use, the tubular stopper rod was, as a rule, straight.

Observations showed that after completion of pouring and disconnection of the air, the temperature of the tubular rod rose on the average to 800°C, due to the heat accumulated in the refractory stopper sleeves. On this account, when the slag was poured from the ladle after completion of steel pouring, the rod sometimes bent somewhat, but this was easily rectified by a subsequent straightening operation.

After some heats had been poured, it was observed that metal had penetrated to the rod through the joints between the stopper sleeves. The thickness of the metal fins between the stopper sleeves did not, however, exceed 2-3 mm, while in the case of deformation of uncooled stoppers, fins 6-8 mm thick were observed. The principal cause of metal fins between the joints of stopper sleeves must be considered to be the unsatisfactory quality of the mortar used for luting.

The wear of stopper tubes in the use of air-cooled rods was studied at the same time.

Steels of different sorts were poured in approximately the same conditions: the average thickness of the slag layer in the ladle was 218 mm, the temperature of the metal before deoxidation was 1623°C and the duration of pouring was 110 min†. In these conditions, the wear of the stopper tubes for different rimmed and killed carbon steels was practically the same, being 10-11 mm for tubes of the Zaporozhsk plant, 8-9 mm for tubes of the Prosyanovsk plant, and 7 and 6 mm respectively in the case of alloy steels. The slag layer has a similar effect on the wear of stopper tubes in the case of both cooled and uncooled stoppers. On the whole, the stoppers wear uniformly. When rimmed steels are poured, however, the stopper tubes wear more rapidly. Their maximum wear was 27-37 mm. It should be noted that when rimmed steels were poured with a slag layer in the ladle 450 mm thick, the wear of tubes of the Zaporozhsk plant attained 47-57 mm, but in that case, the stopper was not deformed.

In September 1959, the open-hearth shop at the Stalinsk plant went over entirely to the use of air-cooled stoppers. Since there were no low-carbon steel tubes at the plant, tubes of steel 40Kh, 57 mm in diameter and

†Including tapping and period of holding the metal in the ladle.

Causes of Trouble in Pouring Heats Using Air-Cooled Stoppers

Item	Steel type			
	rimmed steel	killed carbon steel	56C2, 60C2	alloy steels
Total number of heats poured	33	54	15	41
Number of heats poured with trouble	2	2	–	3
Including				
a) due to fracture of stopper head:				
on first opening	1	–	–	1
at end of pouring	1	1	–	–
b) due to wear of nozzle brick	–	1	–	2

wall thickness 10 mm were used for making the stopper rods. An observation was made in September on the pouring of 143 heats. A period of 20-35 min elapsed from tapping to the moment at which cooling air was connected up. In the case of individual heats, for some reason or another, this time was increased to 50 min.

As will be seen from the table given for 7 heats in which trouble was experienced in pouring, there were no cases of stoppers burning through. After repeated use of hollow stopper rods made of steel 40Kh, however, cases of burning of stoppers during pouring were noted. Observation showed that when the tubular rods of steel 40Kh were straightened, a large number of cracks were formed, due to the high brittleness of the steel, in consequence of which the rods broke. Furthermore, the low weldability of tubes of steel 40Kh was noted; there were cases of failure of the tubular stopper rods along the welds before they were used.

From November, 1959, the open-hearth shop began to use tubular stopper rods of 20 t steel, which is easily straightened and welds well. Rods of steel 40Kh have been taken out of service.

The length of service of air-cooled stopper rods is very much greater than ordinary rods. The average life of 50 stopper rods was 20.3 heats.

It should be pointed out that on changing over to the use of cooled stoppers, the amount of labor for preparing and repairing stopper rods is greatly reduced, as is also the loss of metal.

Solid stopper rods are straightened after each pouring and their lower part is replaced for a length of 0.8-1.0 m. After being repaired four times, a rod is discarded.

Tubular stopper rods need only slight straightening, and only in 10-15% of the rods is the damaged screwthreaded part (for screwing on the head) replaced. As a result, the consumption of metal and the labor expended on preparing and repairing the rods have been reduced to 1/5-1/6. The loss of metal has also been reduced from 0.06 to 0.0.2%. The use of cooled tubular stopper rods is thus advantageous both technically and economically.

The following conclusions may be made on the basis of the results of the introduction of cooled stoppers.

The use of air-cooled stoppers eliminates cases of burning of stoppers during pouring, improves the work of the stopper, increases the length of service of stopper rods, considerably reduces the amount of labor on the straightening and repair of stopper rods, and does not introduce any additional difficulties in the organization of the work of assembling and drying the stoppers and in pouring the steel.

A technical and economical calculation concerning the use of stoppers in the conditions of the open-hearth shop of the Stalinsk plant shows that the annual saving is about 250,000 rubles.

* * *

OUR EXPERIENCE OF STUDYING AND COMBINING ASSOCIATED PROFESSIONS

P. L. Pirozhenko

Master of the Electric-Arc Furnace of the Shaping-Cast Shop
at the "Azovstal'" Plant
Translated from Metallurg, No. 4, p. 24,
April, 1960

Previously a steel maker, assistant steel makers, and a control panel machinist participated in the operation of the electric-arc furnace of the shaping-cast shop at the "Azovstal'" Plant. The steel maker gave orders to the machinist to turn on the furnace, to check the current and voltage at the electrodes, to switch the transformer over to the "wye" or to the "delta", etc. In addition to this, the steel maker checked the instruments of the furnace. Frequently the machinist caused a disruption in the melting process, as a consequence of which melting was delayed, the consumption of power increased, and the quality of the metal lowered.

In the absence of the steel maker, the assistant steel maker, the pourer, or the control panel machinist there was no one who could take their place.

This was reflected in the production rate. We therefore decided to study the associated professions and, as much as possible, to combine the work of the steel maker and the furnace control panel machinist so that each member of the brigade could, if necessary, replace his comrade.

The control panel machinist, actually, does not participate in charging, servicing the furnace and in other operations, and during the melting of the charge the steel maker is free of work. Consequently, by studying the professions of the machinist and the steel maker it is easily possible to combine these two specialties by making certain changes and additions in the electrical equipment of the furnace. We organized a school in the electric-arc furnace section in order to study and combine associated and unassociated professions. This enabled many workers to master a second and third specialty.

Comrades V. Vyvenko, P. Lavrenko, S. Kornaukhov, B. Kostash, and others now have the specialties of a steel maker, a pourer, and a furnace control panel machinist and for about a year have successfully combined the professions of a steel maker and a control panel machinist. The control panel machinists who have been released are used on the bridge cranes.

Assistant steel makers M. Starodubtsev, N. Yefremenko V. Druzik, A Sergiyenko, et al., and pourers A. Teslenko, G. Fokov, and A. Klimenko can now also work as assistant steel makers and steel pourers. All this made it possible to improve somewhat the organization of labor and to eliminate disruptions in production. Now any worker of the brigade of steel makers can be replaced or change positions in the section.

Indian specialists are studying the production practice in the shaping-cast shop of the "Azovstal'" Plant. Recently they received a letter reporting that in September 1959, a five-ton electric arc furnace would be put into operation in India with the help of Soviet engineers. The Indian specialists studying the production practice in our shop will service it for the most part. The steel makers of this electric-arc furnace will also operate without control panel machinists.

A study and combination of related professions can be organized in many sections of work, especially among the shift and repair personnel of the cast and other shops. This considerably widens the technical scope of the workers which is reflected positively in the quality of the products and in their cost.

* * *

TWO METHODS FOR COLD ROLLING SHEET STEEL IN CONTINUOUS FIVE-STAND MILLS

M. A. Leichenko

Central Scientific Research Institute for Ferrous Metallurgy

Translated from Metallurg, No. 4, pp. 25-27, April, 1960

The system of reductions and the corresponding speeds in the cold rolling of sheet steel in modern high speed five-stand mills are shown in the diagram and in Table 1.

It can be seen from the diagram and Table 1 that, in the cold rolling of sheet steel in modern high speed five-stand mills, the reduction in the first stand is much less than in the other four stands and the reduction in the fifth (last) stand is greater than in the first, third and fourth stands.

The system of reductions given here is typical for cold rolling of sheet steel in high speed five-stand mills in the USA and Britain.

The data given in Table 1 are from a report by Soviet rolling mill specialists (B.P. Bakhtinov, S. P. Antonov, et al.) who visited England; the reductions refer to the five-stand mills of the Trostre and Velindre Plants.

The plan for the cold rolling of 0.25 mm gage sheet steel in the five-stand mill of the Magnitogorsk Metallurgical Combine included a system of reductions shown in Table 2.

It follows from Table 2 that the system of reductions in the stand planned for the Magnitogorsk Combine corresponds to the previously established arrangement used in our plants. This is, that in each successive stand, as the metal becomes thinner and the degree of work-hardening increases, the relative reduction is reduced and in the last stand it is only 4-15%.

In our opinion, the method for rolling sheet steel given in Table 1 is better than that given in Table 2.

One of the reasons making it necessary to have smaller (about 11%) relative reductions in the first stand of these mills is in order to obtain a uniform thickness of metal along the length of the roll. It is known that the relative fluctuation in thickness of the metal is considerably reduced with small reduction of the nonwork-hardened metal; in the first stand where the nonwork-hardened metal enters it is therefore desirable to have more reductions.

It is obvious that uniformities in the thickness of the metal should be attained in the first stand where the peripheral speed of the rolls is still comparatively small. The subsequent stands operate at correspondingly higher peripheral speeds of the rolls and the unevenness in the thickness of the metal under these conditions, due to the change in tension between the stands can lead to breakdowns. This is why there is a reduction of about 11% in the first stand in the established method of rolling and why there is a special micrometer to check the gage of the metal at the first stand.

The comparatively high reduction of the metal in the last stand (42%) is explained not by the necessity for obtaining the required thickness of the metal and compensation of the small value of reduction in the first stand but by other technical factors also.

To roll 0.25 mm sheet steel with reductions of about 10-15% in the last stand, this stand should receive metal with a gage of 0.28-0.29 mm. With high rolling speeds even small changes in the gage of these thin strips can cause changes in the strip tension which can lead to the strip tearing or to "slashing" of the rolls.

With a 42% reduction the last stand should receive a strip of gage 0.25: (100-42)/100 =0.43 mm. In this case, when the gage of the metal entering the fifth stand is

TABLE 1. System of Reductions in the Stands (USA, Britain)

Number of stand	Thickness of strip, mm		Reduction		Total reduction, %
	before the stand	after the stand	absolute mm	relative, %	
1	2.25	2.0	0.25	11.0	11.0
2	2.0	1.08	0.92	45.0	52.0
3	1.08	0.67	0.41	39.0	70.0
4	0.67	0.43	0.24	36.0	81.0
5	0.43	0.25	0.18	42.0	89.0

TABLE 2. System of Reductions in the Stands (Magnitogorsk Steel Combine)

Number of stand	Gage of metal, mm		Reduction during pass		Total reduction, %
	before pass	after pass	mm	%	
1	2.2	1.2	1.0	45.5	45.5
2	1.2	0.63	0.57	47.5	71.4
3	0.63	0.40	0.23	36.5	81.8
4	0.40	0.28	0.12	30.0	87.3
5	0.28	0.25	0.03	10.7	88.7

greater than (0.43–0.28) 100/0.28=54%, the possibility of the strip tearing between the last two stands or the rolls being slashed due to change in tension because of the small difference in gage of the strip, if not completely eliminated is, in any case, considerably reduced.

Operating experience of the five-stand cold rolling mill of the Magnitogorsk Combine showed that the rolling of sheet steel with the reductions given in Table 2, in which the reductions are large in the first, and small in the last stand was practically impossible even with comparatively low rolling speeds (less than 10 m/sec) due to the strip tearing, the rolls being slashed and other mishaps occurring.

Only by increasing the reduction in the last stand and reducing it in the first stand was it possible to carry on with the cold rolling of sheet steel to any extent in this mill. An important point here is that the more the reductions on the Magnitogorsk five-stand mill approached those given in Table 1, the more reliable was the operation of the mill.

On the other hand, every time the engineers reverted to the system of reductions given in Table 2, there was an increase in the tearing of the strip, the slashing of the rolls and other mishaps.

It was mentioned above that one of the reasons for using small reductions in the first stand of five-stand mills when rolling sheet steel is in order to reduce differences in gage along the length of the roll. However, there is another no less important reason for having small reductions in the first stand. With the method previously used (Table 2) the convexity (profiling) of the rolls was determined by the necessity for compensating their bending. With this method the metal left the stand with a more even thickness along the width but with thin edges and usually with a double convex shape across the section with thin edges. With the old method it was considered not only undesirable but even impossible to have a strip with a double concave section.

With the new method of rolling sheet steel on modern high speed five-stand mills, the cross section of the metal in the first stand is purposely given a double concave shape, which is obtained by small reductions (11%) in the rolls having a 0.04 mm convexity.

A check which we carried out on reductions under the conditions of the five-stand mill at the Magnitogorsk Combine confirmed that, in actual fact, in the first stand with small reductions the metal has a double concave curvature in its cross section almost entirely corresponding to the roll profiles.

In accordance with the accepted method for rolling in modern mills (Table 1) the cross section of the metal on leaving the first stand acquires a double concave shape whereas with the old method (Table 2) at high reductions in the first stand the section of the metal was double convex on leaving the stand.

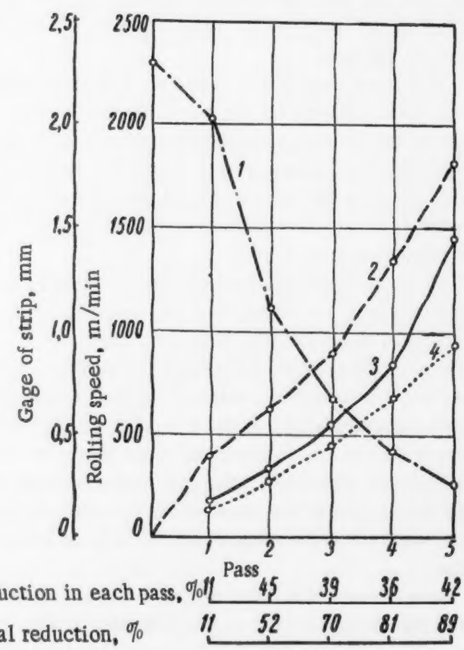
As can be seen from the diagram, in the second stand the relative reduction of the metal is 45%. It is obvious that with such a large reduction the pressure on the rolls and consequently the bending of the rolls will be so great that the section of the metal leaving the second stand will lose its double concave shape, the more so since the degree of work-hardening of the strip before entering the second stand is only 11%.

In order to retain the double concave shape of the strip after the second stand, the rolls of which also have a 0.04 mm convexity, in the rolling of sheet steel palm oil is added to the metal only from the top from one spray placed in the middle of the strip. This sets up conditions which favor the reduction of specific pressure along the arc of contact in the middle of the roll body as a result of which the double concave shape of the metal is retained after the second stand.

With the accepted method for cold rolling on modern five-stand continuous mills the cross section of the strip on leaving the first and second stand has a double concave shape.

The rolls of the other three stands are machined to a cylindrical shape, i.e., they do not have convexity. The cold rolling in the cylindrical rolls in the last three stands therefore draws the metal, with the double concave section of the strip gradually changed to rectangular.

Oil is fed to the metal in the last three stands in the following way: before the third stand –through five sprays on the top surface of the strip, before the fourth and fifth stands–through ten sprays in groups of five to lubricate



The rolling speed in passes at a five-stand strip mill from the data of Powell. Width of the strip 730 mm: 1) gage of strip; 2) highest rolling speed with 550 mm diameter work rolls; 3) average rolling speed: 4) lowest rolling speed.

the top and bottom surfaces of the metal before each stand.

It is obvious that the amount of oil per unit of surface of the metal entering each stand should be constant and hence the amount of oil fed to the metal before each stand (before the first stand the oil is not fed on to the metal) should be inversely proportional to the gage of the metal entering the stand.

It is obvious that the rolling of metal having a double concave cross section using cylindrical rolls in the last three stands will ensure edges without jagged sections which is very important when rolling sheet steel and thin strips.

In the rolling system given in Table 2, there is a large reduction in the first stand (45.5%). Due to the large bending of the rolls on leaving the first stand the metal has a double convex shape, despite the fact that the upper roll had a convexity of the order of 0.12-0.15 mm.

In the succeeding stands, due to the comparatively large reductions and the work-hardening of the metal, the double convex cross section of the metal is retained, which indicates the over-compression of the edges. This uneven deformation of the metal along its width leads to the formation of cracks at the edges and with high rolling speeds this often causes strip tearing and breakdowns.

The new method gives a uniform gage along the length of the rolls after the first stand, high reduction in the fifth stand and consequently an increased thickness of metal between the last two stands, low convexity of the rolls of the first two stands and a cylindrical shape in the rolls of the last three stands; in addition, good edges are obtained. All these features are characteristic of the new method for cold rolling of sheet steel and show that it is better than the method planned for the Magnitogorsk Steel Combine.

* * *

NEW LUBRICANTS FOR THE COLD ROLLING OF STEEL STRIP

I. K. Tokar' and I. A. Chamin

Translated from Metallurg, No. 4, pp. 28-29, April, 1960

Despite the rapid increase in production of cold rolled strip and sheet steel, certain problems, particularly in increasing the speeds of cold rolling, are being slowly solved due to the absence of efficient lubricants. Furthermore, it has become necessary to have new lubricants for the cold rolling of new alloys and difficult to deform steels. In general, mineral oils and their water emulsions do not satisfy the conditions for cold rolling of thin sheets, and palm oil at rolling speeds above 20 m/sec is unable to withstand high power and thermal loads, it rapidly oxidizes and does not reduce sufficiently the external friction between the work rolls and the strip. The polymerization products of palm oil contaminate the metal surface and thereby introduce difficulties in their degreasing, they speed up corrosion and reduce the quality of the sheet. Palm oil is an expensive imported product and hence must be replaced by lubricants produced in this country.

Experiments carried out at the Central Scientific Research Institute for Ferrous Metallurgy* on cold rolling mills showed that oils and fats with a vegetable and animal origin resembled palm oil in their physical and chemical properties. Rape and castor oil, lard, bone, beef and mutton fat can successfully replace the expensive product. Furthermore, castor oil, beef and mutton fats are superior to palm oil in their effect on the rolling process.

Of course, an important drawback in animal fats is their rapid oxidizability at high temperatures in a humid medium in the presence of a metal. For this reason, animal fats must not be used for cold rolling without the addition of special antioxidants.

On the basis of animal fats the Central Scientific Research Institute for Ferrous Metallurgy together with the All-Union Scientific Research Institute for the Dairy Industry have developed and tested under production conditions a number of lubricants for the cold rolling of thin steel sheets. Low carborn steel sheets (0.1% C) were rolled on a four-high mill 180/370×400 mm with a peripheral speed of the working rolls of 21 m/min.

The following conclusions were drawn from the experiments:

1) Almost all lubricants based on animal fat (bone and beef fat) ensure better drawing of the metal during cold rolling and consequently, are able to reduce the

*Those taking part in the work were: I. D. Samoilov, V. A. Gamershtein ("Zaporozhstal'" Plant), I. I. Elin, F. S. Lednikov, I. A. Ostrovskii, E. M. Kontsevaya ("Serp i Molot" Plant), M. A. Leichenko, V. V. Zaitsev and V. D. Kolomatskii (Central Scientific Research Institute for Ferrous Metallurgy).

coefficient of friction to a much greater extent then palm oil;

2) The best results were obtained using the VNIIMP No. 2 and No. 6 oils, consisting of beef fat containing 3 and 5% free fatty acids.

To provide more rigorous conditions in the testing of these oils, tests were carried out on the 222/600×650 mm mill of the "Zaporozhstal'" Plant with a rolling speed of 72 m/min.

Sheet steel was rolled with rolls weighing up to 1000 kg. The results for the cold rolling of 0.28×370 mm sheet steel with the processed beef fat containing 3 and 6% free fatty acids, indicate that these oils are more effective than palm oil, they reduce the friction between the metal and the working rolls. Meanwhile, the quality of metal is unchanged. Furthermore, oils based on animal fats make it possible to roll thin steel sheets with greater reductions than in the case of palm oil. The loads on the mill motor, the pressure of the metal on the rolls and the resistance of the metal to deformation when using beef fat are much less than with palm oil. Active antioxidants must be added to these oils to stabilize their properties†. The All-Union Scientific Research Institute for the Dairy Industry and the Central Scientific Research Institute for Ferrous Metallurgy together with the All-Union Heat Engineering Institute have developed effective lubricants for the cold rolling of steel strip: table fat—a product from the processing of pigskins; stearin—a product from the crystallization of bone fat, modified beef fat.

These lubricants were used for long periods under production conditions in a 180/600×650 mm reversing mill in the cold rolling of thin stainless steel sheets.

When rolling from hot rolled material of thickness 2 mm, using an emulsion of mineral oil, strips of gage 0.8 mm are obtained in six passes, their further rolling becoming difficult due to the increasing pressure of the metal on the rolls. When rolling with table fat and stearin, with the permissible pressures of the metal on the rolls, in eight passes a strip is obtained with a final gage of 0.6 mm.

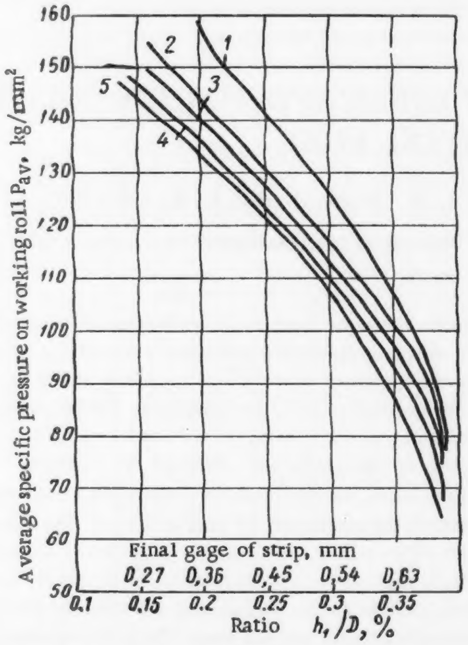
In cold rolling using a water emulsion of mineral oil (diagram) on cold rolled material of 1.0 mm gage in six passes, strips were rolled of 0.4 mm gage, whereas with the same number of passes with stearin, strips were obtained with 0.3 mm gage. When using table or beef fats, strips with this gage are obtained in five passes. From cold rolled heat-treated material of 0.8 mm gage, when using an emulsion of mineral oil strips of 0.4 mm gage, are rolled in four passes, and the use of beef fat reduces the number of passes to three. In the cold rolling of thin sheets with animal fat lubricant, due to the increase in the partial reductions in the passes, it is possible to have a larger deformation of the strips compared with the water emulsion of mineral oil. Thus, using stearin as the lubricant, with the permitted pressures of the metal on the rolls, and loads on the mill motor starting with 0.8 mm gage material, a strip was obtained with 0.2 mm gage in six passes, and in eight passes—0.1 mm gage.

The use of animal fat lubricant at the "Serp i Molot" Plant has considerably intensified the process for cold rolling stainless steel strip, especially when rolling thin strip (less than 0.5 mm gage).

The use of surface active lubricants instead of the relatively ineffective water emulsion of emulsol "B" on two reversing mills at the "Serp i Molot" Plant will give an annual saving of about 900 thousand rubles in the production of stainless steel strip.

The following conclusions were drawn from experience in operating animal fat lubricants.

With reduction in the ratio of the final gage of the rolled strip to the diameter of the working rolls, with increase in the degree of cold working of the strip and



The effect of various lubricants on the cold rolling of stainless steel sheets (1Kh18N9T steel). Strip width 400 mm, initial gage 1 mm: 1) water emulsion of mineral oil (standard emulsion "B"); 2) a mechanical mixture of B106 oil (stearin); 3) a mechanical mixture of beef fat with water; 4) a mechanical mixture of B99 oil (table fat) with water; 5) a mechanical mixture of castor oil with water.

† The laboratory of the All-Union Heat Engineering Institute under the direction of Professor K. I. Ivanov has developed a number of active antioxidants for animal fats. The most active complex addition is yanol (0.4% of the fat) together with an intensifier VTI-8 (0.02%).

the reduction per pass, the effective reduction in friction by surface active lubricants (based on animal fats and castor oil) is improved.

In the production of thin steel sheets with increase in the partial reduction, when surface active oils are used there is a considerable reduction in the number of passes during rolling. This represents a source of possible increase in output for existing cold rolling mills.

In the manufacture of difficultly deformable strips, increasing the partial reductions in the passes reduces the number of heat-treatment operations. Furthermore, in the production of stainless steel strip there is a reduction in the number of pickling operations. These measures considerably reduce the consumption of metal during pickling and annealing. This leads to a reduction in the cost of the finished strip and to the time for processing and also increases the output of the strip rolling sections.

At operating mills the intensification of the cold rolling processes by increasing the partial reduction in the passes will make it possible to raise their output and reduce the cost of the finished production without capital expenditure on reconstruction.

* * *

ROLLING HIGH SPEED STEEL WITH SQUARE PROFILES

P. P. Zuev

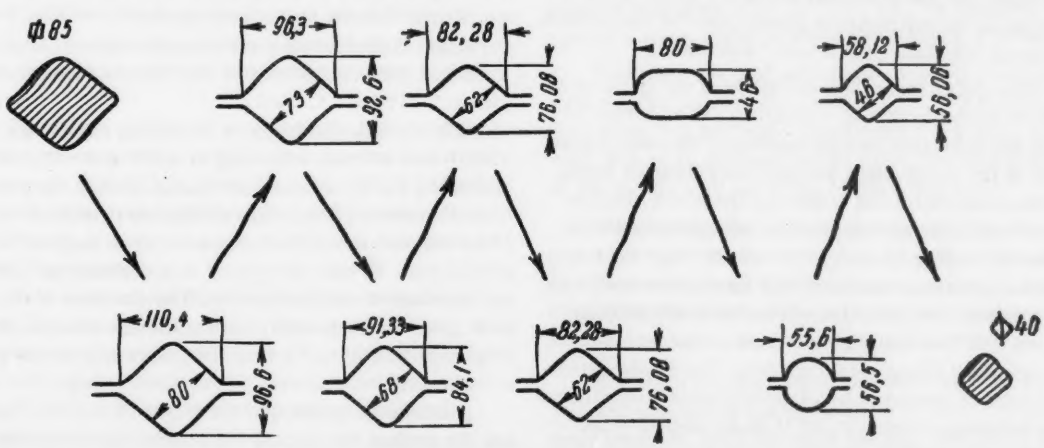
Head of the No. 1 Rolling Mill of the "Elektrostal'" Plant
Translated from Metallurg, No. 4, pp. 30-31, April, 1960

High speed steel is one of the difficult to deform steels having a narrow plasticity range.

Considerable difficulties are involved in the production of square profiles of medium and small dimensions of 40-8 mm of high speed steels on in-line mills. To produce correct square sections without jagged parts on the corners it is very important to have a correct selection of the groove shape and the rolling system.

Previously at the "Elektrostal'" Plant in the rolling of R18 steel in a reduction stand the system used was rhombic-rhombic and in the finishing line rhombic-square. When rolling strip in rhombic and square grooves its corners were not renewed and with reductions in the section of the strip the angles became sharper, which led to intensive cooling and to a sharp drop in plasticity. A considerable quantity of metal rolled with this system was rejected in the final inspection because of large cracks at the corners. For this reason, changes were introduced into the method: intermediate heating was used and in the first stand of the finishing line the rhombic and square grooves were replaced by flat and circular grooves.

With this method a billet of 85 mm^2 section was rolled to 40 mm^2 section, then cut up at the shears into parts with a length not exceeding the width of the furnace and then sent for heating in a furnace immediately adjacent to the first finishing line. After this, the intermediate billet was rolled on the finishing stand of the finishing line made it possible to displace the rapidly cooling corners to the sides of the strip and thereby restore an even temperature throughout the section. The rolling was



A new arrangement for rolling a 40 mm rhombic section on a 450 mill

finished at not less than 950-900°, i. e., within the temperature range of plasticity of R18 steel. The square was obtained without cracks on the corners.

However, this method led to a reduction in the output of the mill, to an increase in the loss of metal in scale and to an increase in the thickness of the decarburized layer, furthermore, the use of a circular groove before the finishing groove did not produce a square with sharp corners—two opposite corners of the square were blunt.

The plant engineers developed a new system for rolling on the reduction stand which was free from the above faults.

This was a combined system: rhombic—rhombic—oval—circle—rhombic—rhombic (see diagram). Rolling to the finished profile on the finishing line was with the system rhombic—square.

Operating with this system gave good results. Replacing the two rhombic grooves with oval and circular grooves meant that the rapidly cooling corners of the previous rhombic section are displaced at first to the sides of the oval and then to the surface of the circle and with subsequent rhombic sections the corners are formed at new places. Furthermore, when a square 62 mm strip passes through a 80×46 mm drawing oval it becomes noticeably heated.

Rolling with the new method meant that without using intermediate heating with the same number of passes on the reduction stand and the finishing line it was possible to increase the output of the mill, to eliminate cracks at the corners of the profiles, to provide sharp angles on the square and to considerably reduce rejections due to decarburization.

* * *

THE CALCULATION AND CONSTRUCTION OF TEMPLETS FOR A FINISH ROLL CIRCULAR GROOVE

M. L. Mirenskii

Roll Design Engineer at the Kuznets Steel Combine
Translated from Metallurg, No. 4, p. 31, April, 1960

In the No. 10, 1959 issue of this journal there was an article by I. M. Konovalov and Z. K. Chaban, "The Design of a Circular Finish Roll Groove." Below we print a reply to this article. *

In connection with the reduction in the positive tolerance in the profile dimensions when rolling steel it is noticeable that the diameters in the hot rolled circle at an angle to the horizontal is greater than the vertical and horizontal diameters (circle with "shoulders").

Attempts to reduce the diameters of the circle at an angle to the horizontal by controlling the clearance between the finish rolls usually resulted in the vertical diameter of the circle being less than the permitted value. The main reason for this is that the finish roll circular groove calculated and constructed according to the old method for rolling circular sections with large and symmetrical tolerances was unsuitable for the new conditions. Consequently, the list of reasons for obtaining circular sections with "shoulders", mentioned in the article by Konovalov and Chaban is incomplete. The displacement of the rolls or passes can be easily and rapidly eliminated in the building of the mill and in these cases it it not necessary to change the groove.

In view of the new conditions for rolling with asymmetrical tolerances the proposal of the authors to reduce the dimensions of the circular finish roll groove is correct but the recommended method for calculating and constructing the templet is complex.

At the Kuznets Steel Combine another way has been developed for calculating and constructing a circular finish roll groove; this method has been published in the journal "Stal' "No. 1, 1957.

The circular finish groove for rolling circular sections of diameter 100 mm according to GOST 2590-57, calculated by the Konovalov and Chaban method has a vertical diameter of 100.4 mm, a horizontal diameter of 101.8 mm and an inclined diameter (at an angle of 45°) of 99.6 mm. To draw the groove it is necessary to make six calculations and six drawings. The diameter of the same groove calculated by our method are equal to 99.8; 102.6 and 99.8 mm. To draw the groove it is necessary to make only two calculations and six drawings.

A simple comparison of the results of the calculation and the method for plotting the templet shows that the Kuznets method is better.

* See English translation.

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DEVELOPING THE PRODUCTION OF BEARING TUBES ON EQUIPMENT WITH A THREE-HIGH ROLLING MILL

Yu. I. Vashchenko

Pervourals New Pipe Plant
Translated from Metallurg No. 4, pp. 32-34, April, 1960

The modern development of engineering has led to increased demands for antifriction bearings. In any given machine these bearings are used with the most widely differing designs and dimensions.

Bearings are assembled at specialized plants from various components: the outer and inner race, balls or rollers and cage. The races are made by various methods: a) the mechanical machining of forgings; b) cutting tubes up into separate components; c) from bars (this method is used to produce small diameter bearings and will not be considered in this article).

The method of making bearing races from tubes is more advanced than the production of races from forgings and is therefore now used to a greater extent, except for the production of large dimension races.

Hot rolled bearing tubes are produced on pipe rolling equipment with automatic mills and also on equipment with a three-high rolling mill. A feature of their rolling is the increased accuracy with regard to wall thickness and the variety of types with a very small difference in diameter and thickness.

At the present time, bearing tubes are rolled from special hypereutectoid ShKh15 steel on specialized equipment only (Fig. 1). Due to the special properties of this steel the production of tubes requires a special production method.

The billets for the tubes are long bars of 100-220 mm diameter. Before rolling they are marked off in the required lengths and are cut on a hydraulic press in the cold state.

The billets are heated in an annular heat-treatment furnace with a rotating hearth with a temperature in the III zone of 1130-1150°, in the IV zone—1150-1170°. The duration of heating depends on the profile of the billet: for 100 mm diameter—1 hour, for 220 mm diameter—2 hours 50 minutes.

To a large extent strict temperature control determines the rolling quality of the bearing tubes, since if the given temperature is exceeded there is overheating of the metal and an increase in the defects on the inner surface, with a reduction in temperature the piercing conditions are spoiled.

The heated billet is brought from the furnace to a special device which punches holes in the front end ("pneumatic gun") and is then pierced on an ordinary two-high inclined rolling mill into a thick walled sleeve. The dimensions of the sleeve are determined by those of the tubes. The temperature limits for the piercing are 1080—1110°. It is checked by a FEP-3 photoelectric pyrometer with a self-recording instrument.

The pierced sleeve is elongated on a rolling mill (Fig. 2) where the metal is deformed by three rolls on a long mandrel. The rolling mill finally forms the wall of the tube and its accuracy is somewhat higher than when rolling with an automatic mill.

Operating experience and literature data confirm that the optimum range of tubes for the rolling mill is with a ratio of diameter to wall of 4-10 (and with some deterioration in the rolling process—11-11.5).

The rolls have a special annular ridge which deforms the wall of the sleeve, the ridge size being selected to suit the dimensions of the tubes. Thus, in an operating installation there are sets of rolls with 8, 10 and 12.5 mm ridges, which have been found to be suitable in the operation of the rolling mill. Due to the wide range of dimensions of the bearing tubes the rolling rate is controlled by changing the speed of the main drive within the limits 320—600 rpm, and the feed of the metal of the sleeve to the center of deformation is controlled by changing the angle of feed from 4°30' to 7°30', i.e., by adjusting the rolls to a given angle of feed before rolling a given tube.

Steel rolls are used with the work surface built up with 3Kh2V8 powder wire under a layer of AN-20 flux. This is the first successful experiment in building up the work rolls of an inclined rolling mill. The long mandrels of the rolling mill are made of 12Kh5MA steel.

After rolling, the mandrel is removed from the tube on a rack-type mandrel extractor; the tube is then sent to a preheating furnace where the temperature is made even along the length of the tube and the mandrel is sent back along a circulating line to the rolling mill.

The tubes are then sized on a three-high sizing mill and intensively cooled in water to 850-700° in a spray chamber. With the rapid cooling, 95% of the bearing tubes could be sent for annealing without preliminary normalization.

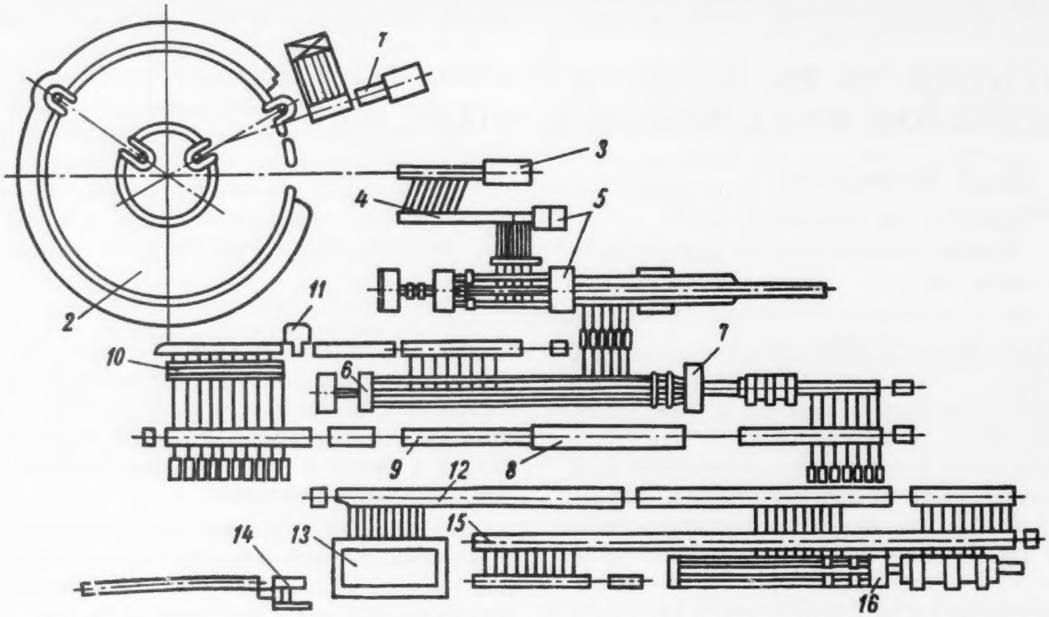

Fig. 1. Arrangement of equipment with a three-high rolling mill: 1) closing machine; 2) annular furnace; 3) feeding machine; 4) roller table; 5) pneumatic centering device; 6) piercing mill; 7) rolling mill; 8) mandrel extractor; 9) roller table for mandrels; 10) bath for cooling mandrels; 11) lubricating machine; 12) roller table before furnace; 13) preheating furnace; 14) ejector; 15) runout table; 16) sizing mill.

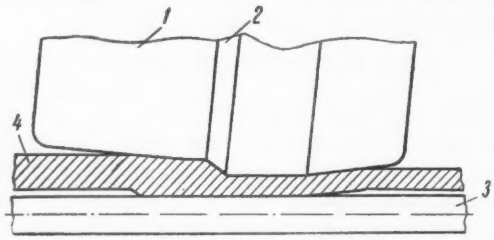

Fig. 2. Rolling system: 1) roll; 2) ridge of roll; 3) mandrel; 4) rolled metal.

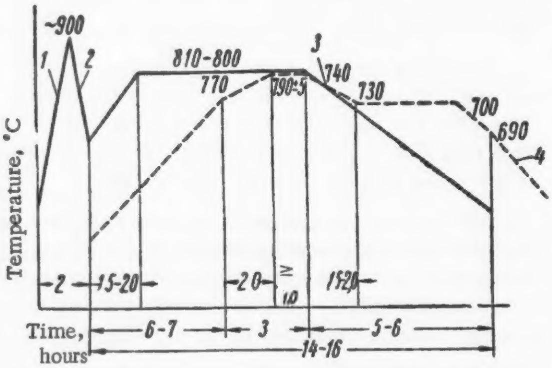

Fig. 3. Graph for the annealing of ShKh15 steel tubes: ——the temperature of the roof thermocuple; ----the temperature from the side thermocouple; 1) heating of the furnace; 2) placing the tube in the furnace; 3) continuous blowing of oxygen into the furnace; 4) in air.

Comparative Data on the Rolling of Tubes on Different Installations

Installations	Dimension of rough tubes, mm	Dimension of finished tubes, mm	Amount of metal removed, mm	Average consumption coefficient
With automatic mill	126×16.25	120.5×11.5	5.5	2.0
With three-high mill during the initial period	124.5×14	120.4×11.2	4.1	1.4
With a three-high mill at the present	122.5×13	120.4×11.1	2.1	1.3

The following is the system for heating the tubes in the preheating furnace:

Wall thickness, mm	Temperature in preheating furnace, °C	Temperature after sizing mill, °C
7–12.5	1050–1000	
13–16	990–950	
16.5–19	950–940	860–900
Above 19	940	

The rolling of the bearing tubes finishes with rapid cooling after sizing. Before the tubes are ready for ship-

ment there is a number of auxiliary operations: heat treatment (annealing), inspection tests, straightening, cutting the ends, turning the outer surface. The bearing tubes are annealed in compartment furnaces with the system shown in Fig. 3. From each charge of annealed tubes specimens are selected for control tests from which rings are cut for metallographic tests. When satisfactory results are obtained for the micro- and macrostructure, hardness, carbide lattice, non-metallic inclusions, and the decarburized layer, the batch of tubes is subjected to double straightening: on an eccentric press (preliminary straightening) and on a seven-high straightening mill (final straightening) to a curvature of 0.7-0.8 mm per running meter.

The straightened tubes enter the tube cutting machines to have the ends cut. The cut tubes with the external flats removed are machined on centerless lathes with an accuracy of plus 0.2—minus 0.0 mm on the diameter. The thickness of the layer removed as a chip varies between 1.5 and 5 mm, depending on the dimension of the tubes being machined. The average thickness of chip removed over the whole range is 2.5 mm. At the start of operation of the equipment with a three-high mill the thickness of metal removed averaged 4 mm, whereas in tubes rolled on the equipment with automatic mill it was 6 mm. The amount of metal removal has been reduced by producing tubes with increased accuracy on the equipment with a three-high mill end also by using in the cutting head of the centerless lathes two tools (instead of the six planned) with T15K6 carbide tips instead of VK8 tips. The table gives comparative data on the rough dimensions of tubes rolled on an installation with an automatic mill and on an installation with a three-high mill in various periods of time. This table gives the average consumption coefficients of metal per 1 ton of finished tubes for the same installations.

On the machined tubes, defective spots are marked for cutting out and the tubes are then cut up into 1-5 m lengths and the defective parts removed. After final acceptance the tubes are lubricated and then put in the stores.

The production of bearing tubes on an installation with a three-high mill has considerably increased the production of these tubes with higher accuracy with a reduction in the consumption of metal and has also reduced their cost by 2 to $2\frac{1}{2}$ times (compared with bearing tubes produced on installations with automatic mills).

* * *

ASSISTANCE GIVEN BY SCIENTISTS ON PRODUCTION PROBLEMS

O. E. Merlo

Translated from Metallurg No. 4, p. 34,
April, 1960

The workers of the roll casting shop of the Dnepropetrovsk Iron Roll Plant decided to ask the scientists of the Dnepropetrovsk Metallurgical Institute to help them solve a number of problems.

The scientists agreed to the request and Professor A. E. Krivosheev came to visit the plant. In the "Red Corner" of the No. 2 Roll Casting Shop various roll casting engineers gathered to hear the scientists. Professor Krivosheev held a three hour consultation and helped the engineers to solve difficult problems on various production processes connected with the improvement of production quality, preventing rejects, increasing output, etc.

In conclusion, the scientists suggested that similar consultations be held at the plant two or three times per month. We welcome Professor Krivosheev and all the scientists visiting the plant shops to give technical assistance to our production workers.

* * *

OPERATIONAL EXPERIENCE OF A RAMMED BOTTOM IN AN ELECTRIC-ARC FURNACE

P. L. Pirozhenko

Master of the Electrical Arc Furnace Section of the Shaping-Cast Shop at the "Azovstal'" Plant

Translated from Metallurg, No. 4, p. 35, April, 1960

Our three-ton electric-arc furnace with a transformer power of 1500 kva was installed in the shaping-cast shop at the "Azovstal'" Plant in 1935.

At first, it operated on a basic bottom rammed with resin. Although exceptionally simple carbon steels were smelted in the furnace the resistance of the bottom did not exceed 300 heats. With time, resin ramming of the bottom was replaced by liquid glass ramming which increased its resistance to 1000 heats. In 1953 the resistance of the bottom had been increased to 2437 heats with a simultaneous increase in the number of alloy and high-alloy steels smelted. But in spite of the strict observation of the instructions for ramming, the bottom frequently deteriorated and was put out of operation. The reason for this was the old technology of ramming. Certain changes were made in ramming technology during the major repair of the furnace in May 1953.

The usual magnesite powder was dried in iron boxes in a gas dryer. We used powder containing 60-63% of 4-7 mm grains and 40-37% of 4 mm and less than 1 mm grains.

A powder containing a greater amount of the fine fraction makes it possible to fill the interstices between the large grains, favors better compaction during ramming and better sintering into a monolithic mass. Each individual layer was slightly lubricated with hot liquid glass, then we covered it and rammed the next layer. In other respects we conducted the ramming according to the operating instructions.

When operating with such a bottom, special attention was devoted to the heat regime while melting the charge. It was necessary to reduce the current when the electrodes reached the bottom. We charged fine lime into the "pits" that were forming. As the metal melted, the current at the electrodes was increased.

When the problem arose of replacing the bottom, the collective of the furnace pledged to increase its resistance to 5000 heats without a major repair This obligation was overfulfilled as the resistance of the bottom was 5740 heats.

There were cases of deterioration of the bottom during operation. In order to repair the bottom and to remove the metal we covered the stagnant sites with a mixture of magnesite (50%) and dolomite (50%) powders and then added a layer of coke 70-100 mm thick and turned on the furnace. As the coke burned new portions of it were added. After 1.5-2 hours of heating, the added material was firmly welded to the bottom.

The coke remains were removed from the furnace and a thin layer of the magnesite-dolomite powder mixture was again added to the bottom. Then we covered the bottom with sheet iron, again added fine lime and started charging. The resistance of the bottom was not lowered after such preventive maintenance. The first heat was usually simple carbon steel.

Careful treatment of the bottom, systematic cleaning of it after tapping each heat, prompt repair of damaged places, and other measures made it possible to attain a bottom resistance of about 9000 heats. The collective of our furnace considers that on a rammed bottom using liquid glass, it is possible to attain a resistance up to 10,000 heats.

* * *

MECHANIZATION OF CERTAIN LABOR CONSUMING OPERATIONS IN THE FORGE SHOP

Yu. T. Khudik and V. A. Lankin

Masters of Forging of the "Dnepr Special Electrical Steel" Plant Forge Shop

Translated from Metallurg No. 4, pp. 36-38,
April, 1960

Forging of the ingots and blanks on five-ton hammers at the "Dnepr Special Electrical Steel" Plant is done by means of forging manipulators of two-ton lifting capacity designed by the "Electric Steel Heavy Machine" Plant. The first such manipulator was received from this plant and the remaining two-ton manipulators were manufactured by the "Dnepr Special Electrical Steel" Plant. Manipulators of one-ton lifting capacity, which were similar to the two-ton manipulators, for forging metal on the three and five-ton hammers, were installed in the shop between the end of 1958 and the beginning of 1959. Their technical characteristics are given below.

Parameters	Manipulators for 5-ton hammers	Manipulators for 3-ton hammers
Lifting capacity, tons	2	1
D_{max} of forging, mm	500	220
D_{min} of forging, mm	150	80
Number of revolutions of holder, rpm	19.1	27.5
Lift of holder, mm	450	350
Descent of holder, mm	200	50

The manipulator (Fig. 1) consists of a framework on a carriage, a mechanism for moving the manipulator, a mechanism for rotating the holder, a hydraulic clamping device for the tongs, anda mechanism for lifting and lowering the holder.

The mechanism for rotating the holder is mounted in a pivot frame and serves to turn the forging. Planetary reducers were installed in the rotating mechanism on the two-ton manipulators and ordinary reducers on the one-ton manipulators. A hollow drive shaft for the holder was installed on the two journal bearings in the pivot frame. The tong head was attached to the free end of the holder.

Clamping of the tongs for holding the forgings is accomplished by a hydraulic system consisting of an electric motor, a wing pump, a by-pass, a valve, and a cylinder with a piston and rod connected to the tong head. The oil delivered from the pump to the front or rear chamber of the cylinder moved the piston with the rod and, together with it, the slide of the lever (tong) head. The tongs of the one-ton manipulator are connected with the slide by blocks (Fig. 2b) moving in the obliquely arranged recesses of the slide; the levers of the two-ton manipulator (Fig. 2a) are connected with the slide by links.

On two of the manipulators the hydraulic clamping device was converted to pneumatic with the utilization of the air from the main line at a pressure of 5-6 atm.

Operating experience with the manipulators showed that the pneumatic clamping device is more reliable in operation since only one control mechanism, a valve, is connected into the system. In this case, longitudinal shock absorption is considerably improved during forging and the clamping and unclamping rate of the tongs is increased. However, due to insufficient air pressure the clamping strength is considerably less than when using hydraulic pressure (10-15 atm).

The lifting and lowering mechanism of the holder serves to move the forging in a vertical direction and consists of an electric motor, a three-stage reducer with two grooved rolls on the exit shaft and of a system of cable sheaves connected to the pivot frame of the holder.

All impact stresses arising when forging the metal and transmitted to the tongs and frame of the holder are received and extinguished by the longitudinal lateral, and vertical spring shock absorbers.

All mechanisms of the manipulator are remotely controlled from a panel arranged in such a manner that the operator sees the hammer machinist and also the forging being worked on the block, and can follow the operation of the manipulator.

The furnaces of the five-ton hammers are equipped with special cars for withdrawing the ingots from the furnace, for turning them into the necessary position and for transporting the ingots to the manipulator. The cars move along rails laid perpendicular to the rails of the manipulator. Turntables with guides made of heat-resistance pig iron and drum-type lifting devices (electric hoists) are mounted on the cars.

The use of the manipulators and cars with turntables frees the forger from heavy work during forging with "crow bars" on with overhead tongs, and changes the forging process from a machine-manual operation to just a machine process. Since the manipulators were introduced a brigade of six men instead of ten is sufficient for assuring normal operation of the five-ton hammer. Each brigade on the three-ton hammers was reduced from eight to six

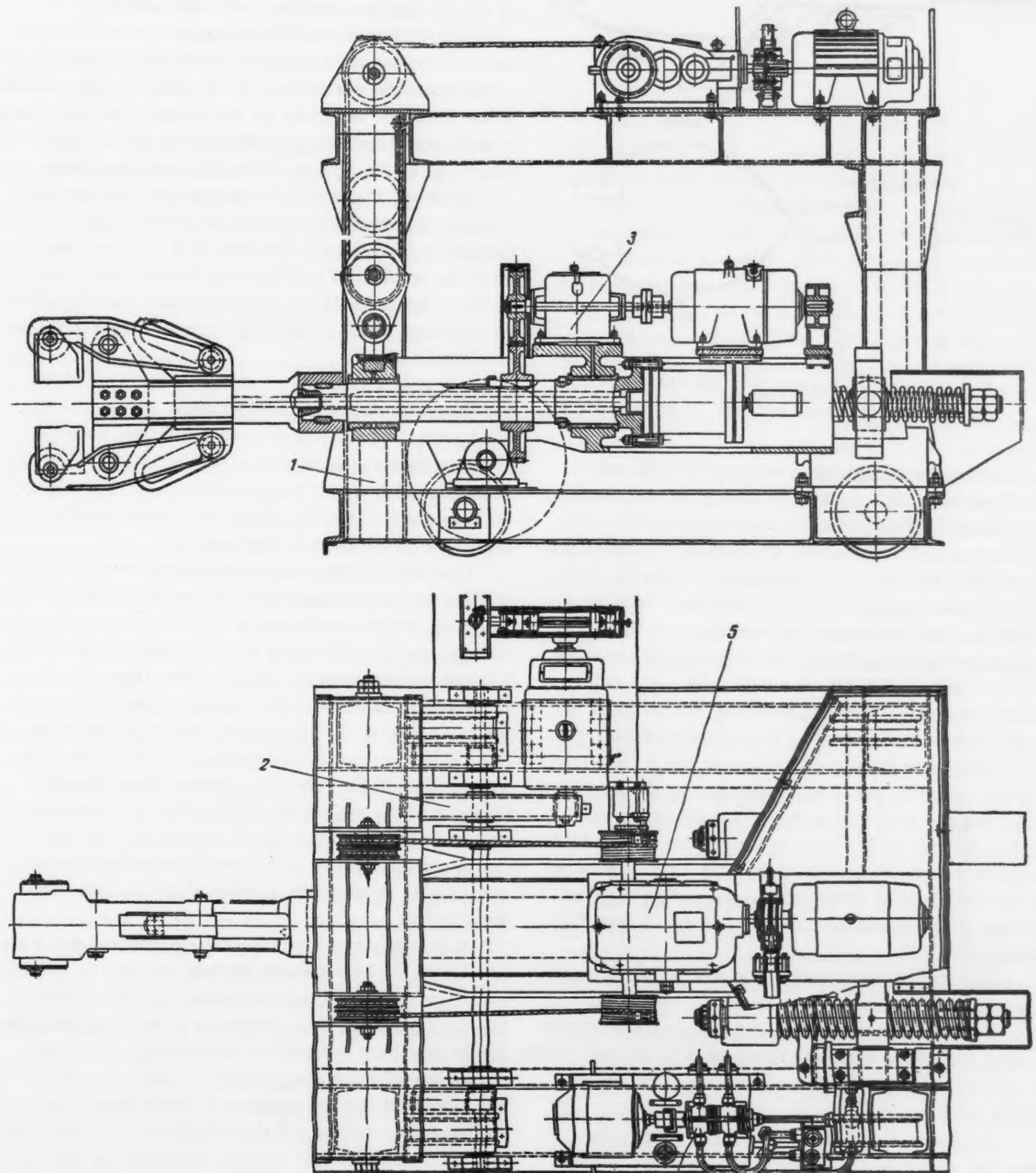

Fig. 1. Forging manipulator of one-ton lifting capacity. 1) Framework; 2) mechanism for moving the manipulator; 3) mechanism for turning the holder; 4) tong clamping device; 5) mechanism for lifting and lowering the holder.

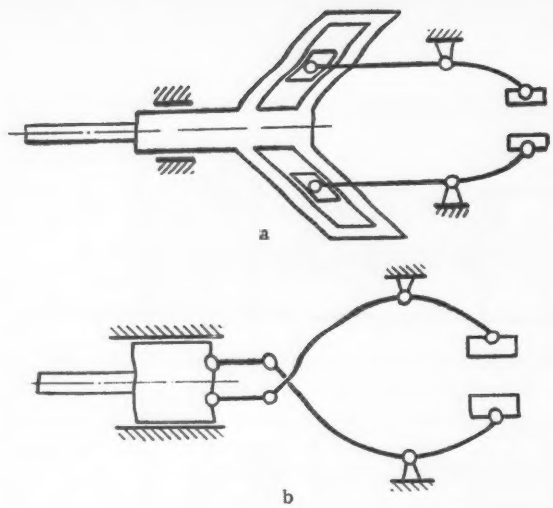

Fig. 2. Functional diagram of the heads of the two-ton manipulators: a) Lever; b) tong.

men with an annual savings in wages of 700,000 rubles.

There was also a qualitative change in the personnel of the brigade. Thus, on the five-ton hammer, only two of the seven forgers remained, the hammer brigadeer and his assistant, but then a new profession developed, that of manipulator operator. Certain operations could be combined. Thus, delivery of the next ingot while forging the preceeding one shortened the ingot forging cycle by 35-40 seconds. Previously, delivery of the ingot to the furnace for heating was done manually by the entire brigade within 40-50 seconds; now delivery of the ingot to the furnace for heating of the second end is combined with the run of the car from the hammer to the furnace for getting and transporting the next ingot to the manipulator; delivery of the ingot to the furnace is done by means of the car while forging the next ingot. The interval between the end of forging the preceeding ingot and the start of forging the next ingot was reduced from 1.5 min to 40-45 sec.

As a result of the measures that were taken to mechanize the labor consuming operations the productivity of labor of the workers on the five-ton hammers was almost doubled and on the three-ton hammers it increased by 33% and will increase more as the operation of the manipulator is mastered.

The change over to operation with manipulators permitted a considerable change in the variety of shop products with an increase in the percent of hard-type steels. It became possible to increase the weight of ingots for a number of hard steels, which made it possible to increase the productivity of the hammers. The use of the manipulators on the three-ton hammers enabled us to increase the weight of the blanks from 150-200 kg to 400-450 kg, which is still not the maximum since the lifting capacity of the manipulator permits a further increase in the weight of the blanks to 800-900 kg. The weight of tubular blanks of stainless steel was increased.

The rhythmical and highly productive operation of the five-ton hammers made it possible to accomplish on a wide scale the hot delivery of the blanks to the furnaces of the three-ton hammers. At the present time large blanks of all types designated for reforging into small blanks are placed hot in the furnace of the three-ton hammers.

However, the use of the manipulators still far from completely solved the problems of mechanizing all labor consuming operations in the shop. It is still necessary to solve the problem of mechanizing the turning of the metal in the furnaces and removal of the hot metal from the hammers which is presently done by means of single-axle hand cars.

It is still impossible to increase the weight of the blanks for the three-ton hammer above 450 kg due to the fact that delivery of the metal from the furnaces to the hammers is done manually. Mechanization of this operation will make it possible to increase the weight of the blank to 800-900 kg, which will correspondingly increase the productivity of the hammers.

Operation of the manipulators revealed certain faults in their design. Unsatisfactory operation was noted in the lift-pivot mechanism having a fixed pivoting axle on the one-ton manipulators while forging strips and sheet-bars, because the considerable change in the angle of arrival of the holder relative to the position of the forging on the block (flat or on edge) causes bowing of the strips.

On the two-ton manipulators cottering of the slide with the rod of the hydraulic cylinder causes frequent breaking of the rod due to considerable concentration of stresses in the rod at the site of the slot. In order to increase the service life of the transmission shaft it was necessary to increase the number of its bearings from three to five.

It is necessary to improve the longitudinal shock absorption of the holder frame because the turning mechanism installed on it operates unreliably under impact loading conditions. The conversion of the tong clamping mechanism from hydraulic to pneumatic to a certain degree helped solve this problem, as was indicated above. But in spite of this the problems of shock absorption must be worked out further. All these faults can be eliminated and do not decrease the value of mechanizing the forging processes in the forge shop.

The wide application of forging manipulators in the forge shop will play an important role in the technical progress of our industry.

* * *

ON THE PATH TO GREAT VICTORIES

Hu Li-tan

Translated from the English by Ya. E. Brodskii
Translated from Metallurg, No. 4, p. 39,
April, 1960

Chinese metallurgy has recently forged ahead at an unprecedented rate. Not having any advantages over other countries, China in the last ten years has attained a stupendous growth in industry, and for the first time in the history of the country had developed its own metallurgy.

Only 7,600,000 tons of steel were produced in old China during 49 years of the Twentieth Century, while after the liberation of the country 39,520,000 tons of steel were smelted in only ten years, i.e., five times more. The difference is rather appreciable. Not one capitalistic country can even dream of such a grandiose rate. From 1949 to 1958 the annual production of steel in China was increased by 54.7% (not considering the metal produced by local methods). During this same period the production of steel in the USA grew only by 1%, in England by 2.6% and in France by 5.3%.

In 1959 the Chinese steel makers, using the latest metallurgical equipment, on the basis of the "great leap" of 1958, increased the production of steel by another 50%. Such unprecedented achievements were mainly attained due to the socialist system of the State and to the steadfastness of the general line of the Party directed toward socialist construction.

Presently in China there are 596 newly built, operating metallurgical enterprises. From the beginning of 1958 (the year of the the "great leap") to the end of 1959, 580 metallurgical enterprises were put into production or were in the stage of construction. Construction of metallurgical enterprises has reached an unequalled tempo in China's history. After the "great leap" only four months and three days were required to construct a 1513 m^3 blast furnace and three months to build two 500-ton open-hearth furnaces. This is a rate unequalled in the history of ferrous metallurgy.

Modern construction foresees a reduction in capital expenditures. If previously it required 1,370,000,000 yuan to construct metallurgical enterprises with an output of 1,500,000 tons of steel, then now only 1,600,000,000 yuan are required in all to construct enterprises producing 3,000,000 tons of steel.

Moving forward "more quickly, more greatly, better and more economically", Chinese metallurgy is successfully overcoming its former backwardness. After starting operatien of the Anshan Combine, construction of the Huan and Paotou Combines, which are modern metallurgical giants, began. Copper and aluminum industries have been newly created in China.

The capital of Chinese metallurgy, Anshan, has one of the largest combines in the world. Here it is possible to see the most powerful blast-and open-hearth furnaces, the latest aluminum and copper smelting enterprises. Due to the policy of the Party—the simultaneous development of large-scale, medium, and small enterprises with utilization of old and new methods of production—and also due to the personal participation of the Chairman of the Party, Mao Tse-tung, Chinese metallurgy reached an unparalleled tempo in the year of the "great leap."

The idea of constructing metallurgical enterprises has seized the entire Chinese population. A clear illustration of this is that we have attained successes in constructing not only powerful modern blast furnaces, but we have also built thousands of small ones operating according to local techniques. These furnaces produce a large amount of pig-iron and were converted into their own king of "little groups of small, modern blast furnaces", which played and continue to play an important role in the production of metal. Presently the total volume of the small blast furnaces exceeds 43,000 m^3. This year they will produce 10,000,000 tons of pig-iron, which is half of the total pig iron production in 1959.

Such furnaces were constructed in order to increase the output of products, to improve their quality, to reduce capital expenditures, and to attain high indices.

From the spurs of Tien Shan to the shores of the Eastern Sea, from the banks of the Amur to the island of Hainan, almost in each province or autonomous region there are medium and small metal metallurgical enterprises. All this radically changed the geographical setting of the metallurgical industry in China.

During the last ten years not only has the tempo of production grown, but also many different types of products have been mastered. Like alpinists storming the highest peaks, our metallurgists strain to attain the highest level of industry.

We started to develop the technology of vacuum smelting; we attained successes in the production of various types of high-alloy, corrosion-resistant, heat-resistant and instrument steels.

Based on rich raw-material sources the Chinese metallurgists are developing their own system of producing alloys. We have already produced 246 different

alloys. In recent years, especially in 1958 (the year of the "great leap"), large amounts of rare metals have been produced in an experimental arrangement. With these metals we can storm the very unattainable regions of science.

The Chinese metallurgical industry, the base for industrial development of the country, is now on the path to great victories.

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NEW BOOKS

E. K. Larke, Rolling of Sheet and Flat Metal, Metallurgizdat, Moscow, 1959, 384 pages. Translated from Metallurg, No. 4, p. 40, April 1960.

Reviewed by Doctor of Technical Sciences,
E. S. Rokotyan

E. K. Larke's book Rolling Sheet and Flat Metal (translated from English by Candidate of Technical Sciences I. M. Meyerovich under the editorship of Candidate of Technical Sciences E. R. Shor) generalized the theory and practice of rolling flat products made of ferrous and, mainly, of nonferrous metals and light alloys.

The author elucidates in detail the present state of sheet-rolling production and gives a detailed analysis and sample solutions to problems connected with shaping rolls, with variations in the longitudinal thickness of the flat pieces being rolled, with the calculations of the power parameters which occur while rolling the flat product; he shows the effect of the rolling speed, tension, and other factors on deformation resistance; he describes the instruments for measuring various parameters of the rolled product and also cites calculations of the productivity of plate and sheet mills, the consumption of energy and power requirements, efficient regimes of rolling, etc.

A separate chapter of the book is devoted to the problems of the historical development of rolling-mill production in the capitalistic countries.

Of great interest to the readers is the chapter which concerns the problems of calaculating the shape of the rolls for the sheet and plate mills so as to obtain the optimum shape of the flat product and the sheet with consideration of the temperature and pressure effect on the rolls, and the curvature from the effect of the bending and transverse forces. The material in this section is indisputably a serious scientific contribution to the theory of rolling.

The book examines in detail the causes for the formation of different thicknesses along the length of hot rolled and cold rolled strips, including the speed, tension, and temperature of the rolls, the initial difference in thickness, the variations in hardness, and the eccentricity of the rolls. Unfortunately the author does not devote such attention to the transverse difference in thickness, which is frequently of greater interest than the longitudinal difference.

When examining the factors determining the pressure of the metal on the rolls the author chiefly used the materials of English, German, and American scientists in this field. This aspect adversely affected the book and reduced its worth. Taking this into account, the editor, as an appendix, gives a broad list of the works of Soviet scientists in the rolling-mill field.

It is necessary to note the great labor of the translator and editor who, in spite of all the difficulties of the technical text, have successfully coped with the task.

The book is written in simple, practical language and is designed for a wide circle of rolling-mill operators, and in addition to this it is a valuable textbook for students and specialists who are occupied with the problems of sheet and plate rolling production.

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SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosénergoizdat	State Power Engr. Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LÉIIZhT	Leningrad Power Inst. of Railroad Engineering
LÉT	Leningrad Elec. Engr. School
LÉTI	Leningrad Electrotechnical Inst.
LÉTIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MÉP	Ministry of Electrotechnical Industry
MÉS	Ministry of Electrical Power Plants
MÉSÉP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTi	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOÉ	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIÉL	Central Scientific Research Elec. Engr. Lab.
TsNIÉL-MÉS	Central Scientific Research Elec. Engr. Lab.-Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIÉSKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Meteorology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZÉI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us - Publisher.